[redacted]

/BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Interim Mission Sequence Plan for the Encounter Portion of the 1975 Manned Mars Flyby Mission - Case 233

DATE: June 15, 1967

FROM: E. M. Grenning

ABSTRACT

An interim mission sequence plan for the encounter portion of the 1975 manned Mars flyby mission is presented. The time period covered is from the initiation of probe pre-separation operations until probe communications are switched from a Mission Module (MM) to earth receiver.

Operations are described as a function of time in terms of the discrete events and continuous functional modes of system elements. A preliminary command and control structure is established. As an integral part of the operational profile the information flow into the MM as a function of time is divided into that transmitted by the remote probes and that acquired by on-board MM sensors. The two-way information flow between the MM and earth is not covered. The decisions available to the crew (in consultation with earth as appropriate) and the criteria by which these decisions are made are included in the profile. The incorporation of options or alternate paths which the mission may take depending on prevailing circumstances completes the interim description of operations. In each subphase areas needing further study to permit a more precise definition of the operational profile are identified and are briefly discussed in an appendix.

(NASA-CR-154907) INTERIM MISSION SEQUENCE PLAN FOR THE ENCOUNTER PORTION OF THE 1975 MANNED MARS FLYBY MISSION (Bellcomm, Inc.) 41 p

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

1.1 Purpose

The purpose of this memorandum is to provide an interim operational statement of the encounter portion of the 1975 Mars flyby mission currently under study within Bellcomm. It is intended that this interim statement (1) serve as the basis for identifying the role of man on the 1975 Mars flyby mission and (2) provide a focus for identifying mission and systems areas requiring study. An updated version of this mission sequence plan will eventually be included in an operational profile describing the entire mission. Quoted numerical quantities are tentative and are based on preliminary analyses, estimations, and the author's judgment.*

1.2 Scope

The system elements covered are the Mission Module (MM), crew, remote probes, and earth-based control center. The operations and events described are generally limited to those involving the experiments payload during the encounter portion of the overall Mars flyby mission. This period begins at the initiation of probe pre-separation operations and terminates when probe communications are switched from an MM to earth receiver, i.e., at the data rate break even point. The operational sequences involve conceptually defined hardware and are based on currently known mission constraints.[1,2] Included in the operational profile is the visual and non-visual data flow into the MM command and control center subdivided into that transmitted by the remote probes and that acquired by on-board sensors.

1.3 Mission Sequence Plan Structure

The format is modeled after the Apollo Mission Sequence Plan (Bellcomm TR-65-214-1). Within this structure the encounter

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*The numerical values specifically describe the 1975 Mars flyby mission. However, the operations concept with mission peculiar modification of numerical values is applicable to all manned planetary encounter missions.

portion of the mission is described in terms of the following phases: (1) Probe Pre-Arrival and (2) Probe Post-Arrival, both of which are divided into subphases.*

Each phase is presented in two complementary parts, a narrative and a table. Areas which have been identified as needing further study are marked in the text (but not in the phase summaries) with an asterisk, defined in the Appendix, and listed in Table I or II, as appropriate. Areas relying on supporting background information are also marked in the text (not in the phase summaries). The required information is briefly presented in either footnotes or the Appendix, but does not appear in the tables.

2.0 MISSION SEQUENCE

The mission sequence is based on the following:

1. The mission is a 1975 hyperbolic flyby of Mars with periapsis altitude of about 300 km.[3] Velocity at all positions on the hyperbola is assumed constant at 10 km/sec.

2. Spacecraft maneuvers to change MM periapsis passage time, i.e., martian longitude at which MM periapsis occurs, are performed prior to separation of the probes.

3. The system consists of: the crew; the MM, which houses the crew and serves as a command and control center and experiment platform; a Mars Surface Sample Return probe (MSSR), including a Rendezvous Vehicle (RV) used to return a surface sample to the MM; a surface Geophysics Lander (GL); a Photographic Orbiter (PO); and three Aero-Drag Entry probes (AD). Reference 1 contains a conceptual definition of the system.

4. A maximum of six discrete transmission bandwidths is permitted for each probe.**[4]

5. The arrivals of the MSSR, GL, and PO are timed to result in the maximum time compression of operations.

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*Probe arrival is defined as the time of arrival at the target locality in the Mars environment. The target locality for each type of probe is defined in Section 2.1.1.

**See Appendix (2.0 - A)

A listing of the subphases under each phase with approximate durations and transition points is presented in the following table as a general outline of the mission sequence.

PHASES	SUBPHASES	APPROXIMATE DURATION			TRANSITION POINTS
		Days	Hours	Minutes	
Probe Pre-Arrival Phase					Initiation of probe pre-separation operations
	Pre-separation operations	2	17		
					Probe separations
	Injections	2	18		
					First probe midcourse corrections
	Mars approach	2 to 10			
					Arrival of first AD
	Mars arrival	1			
					Arrival of GL
Probe Post-Arrival Phase					PO arrival
	Probe arrivals through check-outs		2	20	
					Completion of GL checkout
	Pre-RV liftoff operations			58	
					RV liftoff
	RV flight			16	
					Rendezvous with MM
	Direct PO photographic readout		15	21	
					Photo quality degradation due to signal-to-noise ratio constraint
	Pre-break even point operations	7	9		
					Break even point

2.1.1 Phase Definition

This phase covers the time period from the initiation of probe pre-separation operations until the arrival of the probes at Mars.

The AD probes arrive early enough to provide atmospheric data for use in final trajectory corrections for the MSSR, GL, and PO. The arrival time of the MSSR is fixed in order to allow just enough time for surface operations prior to in-plane RV liftoff. The GL arrival relative to that of the MSSR is arranged to result in a maximum time compression of operations while avoiding a direct operations conflict. Arrival of the PO is timed to avoid an operational conflict but also to make the injection velocity change as low as possible. The time of arrival of each probe relative to MM periapsis passage, with the definition of its arrival locality, is set forth in the following table.

Probe	Approximate Arrival Time (Hours-Minutes)		Arrival Locality
AD 1	-24		About 220 km entry altitude within approximately 45° central angle from sub-MM point.
AD 2	-20		
AD 3	-16		
PO	- 3	30	About 300 km altitude approximately over North Pole
MSSR	- 2	24	Target landing site
GL	- 2	09	Target landing site

This gross time period is subdivided into four subphases: (1) pre-separation operations; (2) injections; (3) Mars approach; and (4) Mars arrival.

2.1.2 Nominal Mission Phase Description

2.1.2.1 Summary

In this phase the crew prepares each of the probes for separation from the MM by carrying out a sequence which includes subsystems checkout, sterile repair if necessary, and various probe command and control operations. The crew then sequentially commands probe separations from the MM. For each probe, separation is followed very shortly by the automatic execution of injection into its predetermined Mars transfer trajectory. During the transfer, midcourse corrections are applied to the probes as necessary for targeting. The AD probes arrive early enough to provide pre-arrival atmospheric, and possibly geodetic, data for use in final trajectory corrections for the other probes.

The crew performs telescopic Mars photography in parallel with the above operations and, on the basis of photographic data, may make post-injection changes in nominal probe missions within time and propulsion subsystem constraints. The crew performs intermittent optical and radar tracking of the probes and conducts periodic probe subsystem interrogations. The former provides data for midcourse correction computations while the latter allows determination of subsystems status. Throughout this phase the crew controls operations, consulting the earth control center as necessary and when feasible.

2.1.2.2 Subphase Description

2.1.2.2.1 Pre-Separation Operations

The Probe Pre-Arrival phase is initiated with crew performance of probe pre-separation operations. The subphase duration is about 65 hours and the required functions are conducted almost entirely in parallel with those of the injections subphase (2.1.2.2.2).

For each probe there are five basic types of operations that the crew will perform sequentially:

(1) checkout of probe systems;

(2) sterile repair of probe systems, if necessary;*[5]

*See Appendix (2.1.2.2.1 - A)

(3) alignment of probe inertial platforms with MM platform;

(4) command of probe into inertial hold attitude control mode; and

(5) pre-separation insertion in probe memory of injection maneuver attitude and velocity change.

For each of the probe types, the following table presents the estimated durations and information rates needed to perform systems checkout and the estimated time requirements for sterile crew repair.*

Probe Type	Estimated Checkout Duration (Minutes)	Estimated Checkout Information Rate (bps)	Estimated Repair Time (Hours)
AD	5	10^2	6
GL	15	10^3	12
PO & MSSR	15	2×10^3	18

These segments of time are used to construct the subphase profile in modular fashion, thus effecting a degree of flexibility.

The subphase starts for each probe with a systems checkout. If an anomaly requiring repair is detected, the crew must complete the needed repairs prior to the scheduled probe separation. This function consists of an iterative procedure involving appropriate checkouts as the repairs progress. If additional repair time is needed, consideration is given to rescheduling the probe separation for a later time.**

If the systems checkout which initiates the subphase indicates that probe repairs are not required, the nominal mission continues until about 30 minutes prior to scheduled separation. The crew then aligns the probe and MM inertial platforms and commands the probe to remain in an inertial hold attitude control mode. The crew inserts the injection maneuver attitude and velocity change values in the probe memory and initiates the maneuver time sequence. The injection maneuver is monitored by the crew and executed over a period of about 30 minutes after probe separation from the MM.***

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*See Appendix (2.1.2.2.1 - B)

**See Appendix (2.1.2.2.1 - C)

***See Appendix (2.1.2.2.1 - D)

2.1.2.2.2. Injections

Assuming the necessary targeting information to be available, the following sequence of operations and estimated elapsed times are essentially common to all probes.

	Operation	Estimated Elapsed Time (Hours-Minutes)
1.	Deployment of omni-antennas and establishment of communications link	15
2.	Execution of injection maneuver, i.e., attitude and velocity change	30
3.	Establishment of MM-probe visual link	15
4.	Probe acquisition of stellar reference	30
5.	Deployment of solar panels (if applicable) and high gain antenna	15
6.	Probe subsystems checkout	15
7.	Radar and optical tracking	4 - 00
8.	Probe subsystems checkout	15
9.	First midcourse correction maneuver	45
10.	Probe subsystems checkout	15
	Total Elapsed Time -	7 - 15

Nominal targeting for the AD and PO probes is determined prior to earth departure. These probes are injected before the MSSR and GL to allow acquisition of higher resolution photographic information for MSSR and GL targeting.* Targeting of the GL and MSSR is determined by the crew on the basis of optical photographic data obtained during the earth-Mars transfer as well as during the period immediately prior to sequential launch of the two

*See Appendix (2.1.2.2.2 - A)

probes. This latter information consists of 16 photographs taken at 1.5-hour intervals in order to provide good resolution coverage for every 22.5° of rotation of the planet. This requires a duration of 22.5 hours, while optical tracking of the previously launched probes is performed in the 1.5-hour intervals between photographs. Allowing an additional 1.5 hours for final data analysis and targeting decisions by the crew results in a total time requirement for MSSR and GL targeting of about 24 hours. Photography of Mars using the MM telescope subsequently continues with a photograph being obtained every three hours through -3 hours.[6]

The total elapsed operations time of about 7 hours 15 minutes for each probe is used in conjunction with the GL and MSSR targeting requirement of 24 hours to construct the integrated subphase profile.

2.1.2.2.3 Mars Approach

The duration of the probe flights is estimated at between two and ten days during which telescopic photography of Mars continues at a nominal rate of one exposure every three hours, i.e., for about every 45° of planet rotation. The crew evaluates these increasingly higher resolution photographs to determine whether the probe nominal missions should be changed.*

Intermittent optical and radar tracking of the probes is performed by the crew (in parallel with planetary photography) in order to provide the data needed for midcourse maneuvers.**[7] The crew interrogates the probe subsystems prior and subsequent to each midcourse correction to determine subsystems status. Based on the results of the interrogation, the crew decides whether to continue the nominal mission in progress or to proceed with a degraded mission profile. The option of terminating a probe mission in the event of a serious malfunction is available in all subphases.

2.1.2.2.4 Mars Arrival

The early arrival of the AD probes is intended to permit obtaining atmospheric, and possibly geodetic, information prior to the arrivals of the MSSR, GL, and PO probes.*** A data rate of 3×10^3 bps for about ten seconds resulting in a total of 9×10^4 bits of atmospheric information is expected from the AD probes.

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*See Appendix (2.1.2.2.3 - A)

**See Appendix (2.1.2.2.3 - B and C)

***See Appendix (2.1.2.2.4 - A)

The arrival times of the MSSR, GL, and PO are given in the table contained in the Phase Definition (2.1.1). These arrival times are arranged to result in the maximum feasible compression of operations with respect to time. The resulting operational profile is such that only one of the three probes is in communication with the MM at any instant.*

The MM optical photographic sequence of one photo every three hours continues through this subphase with the planetary image just filling the photographic plate for the photo obtained at -6 hours.[8] This photo would contain about 5×10^{10} bits of visual martian surface information. Between -3 hours and -2 hours 45 minutes four photos are obtained which together cover the entire visible face of the planet. This set of exposures provides about 2×10^{11} bits of visual martian surface information.

Because total visible surface area coverage with the telescope system requires an increasingly larger number of photos as periapsis is approached, the required system slewing rates correspondingly increase to a point where they exceed the technological limit.[6] For this reason use of the optical system between -2 hours 45 minutes and terminator crossing (-90 seconds) is relegated to a selective photographic sampling role. This selective photography is regulated by a pre-programmed telescope photographic sequence with provision for crew override.** The pre-programmed sequence is established by the crew in the period from -6 hours to -3 hours and is based primarily on photographs obtained through -6 hours. It is assumed that the sequence would result in an average of about one exposure every 2.5 minutes. The MSSR and GL landing sites would be two of the targets included in the sequence, thus permitting an accurate determination of the MSSR landing site location for later use in initializing RV flight (Subphase 2.2.2.2.5).***

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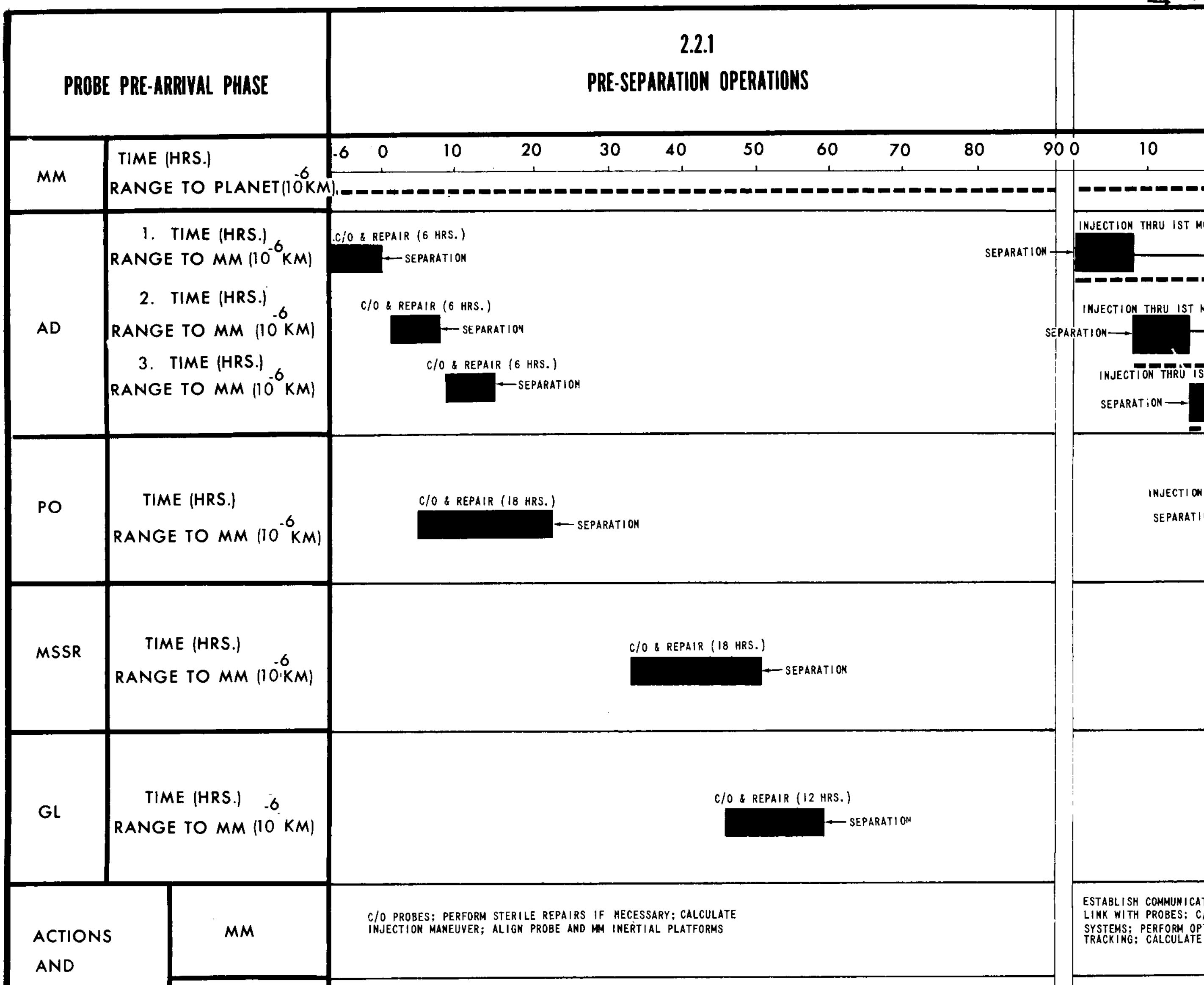
*Therefore, probe-MM operations could be performed using a single MM high gain antenna with a second simultaneously transmitting to earth or being held in reserve as a backup.

**See Appendix (2.1.2.2.4 - B)

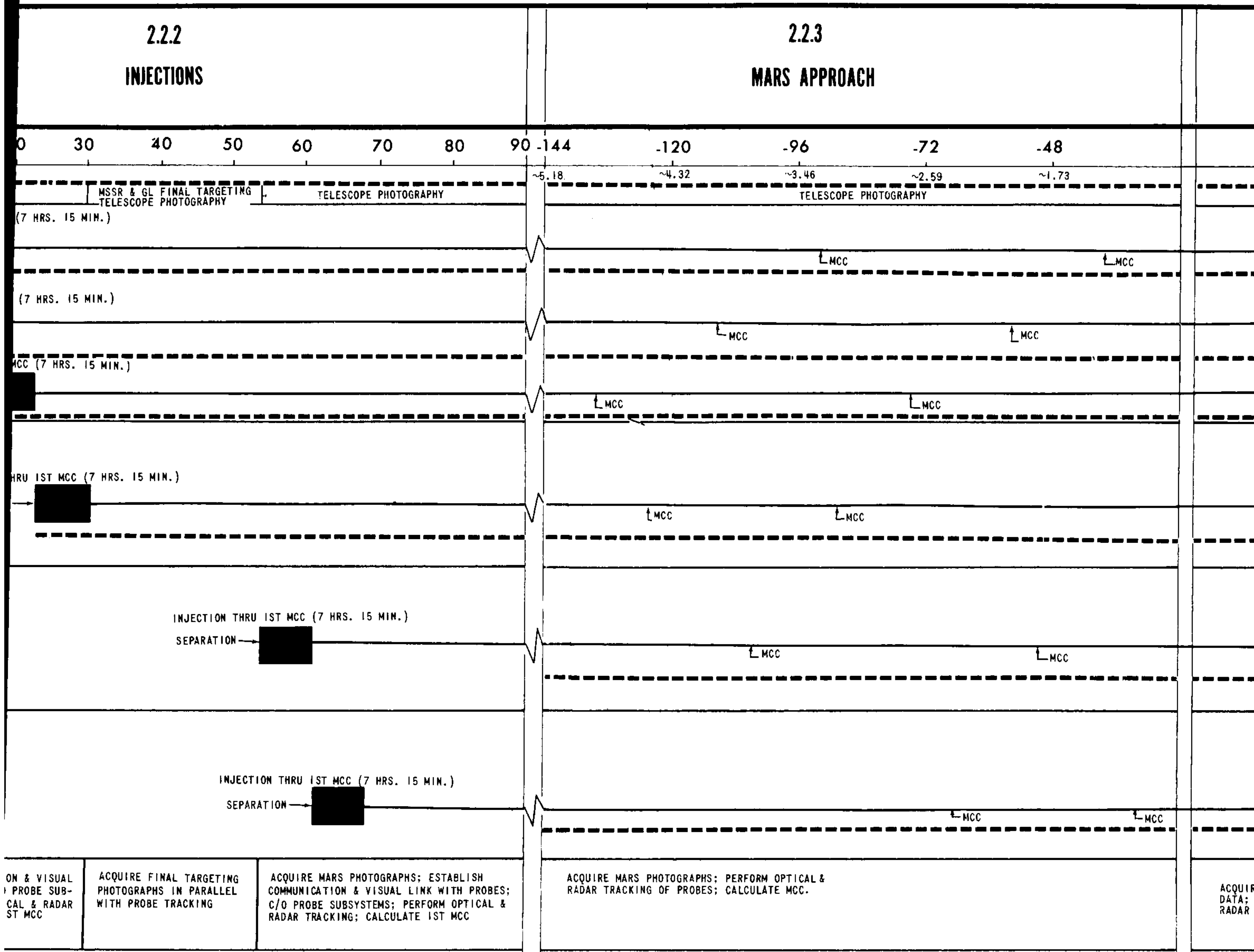
***It is anticipated that a flashing strobe light would be located aboard each of the surface probes.

9-A-1

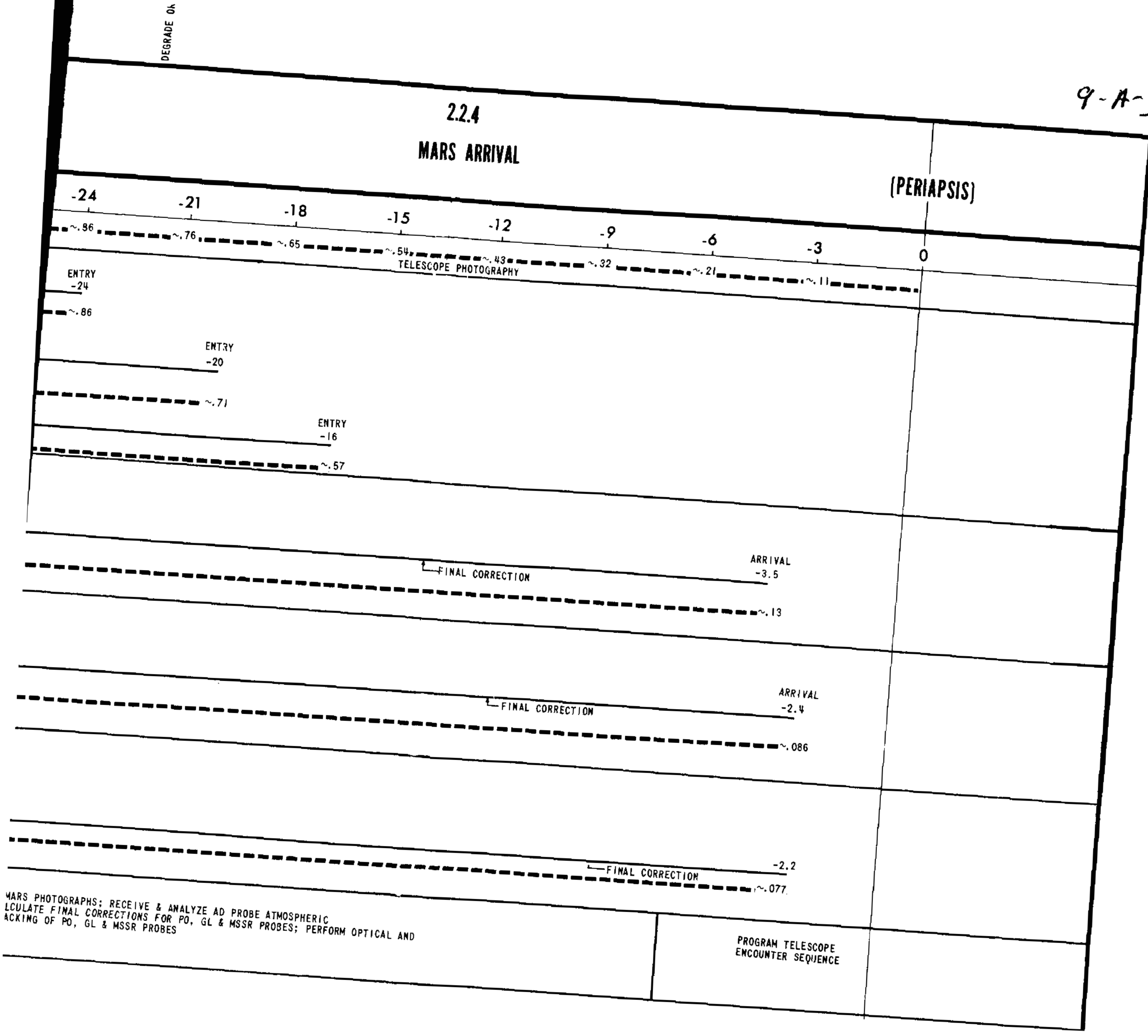


PROBE PRE-ARRIVAL PHASE
2.2.1
PRE-SEPARATION OPERATIONS
MM
TIME (HRS.)
RANGE TO PLANET (10^{-6} KM)
-6 0 10 20 30 40 50 60 70 80 90 0 10
AD
1. TIME (HRS.)
RANGE TO MM (10^{-6} KM)
2. TIME (HRS.)
RANGE TO MM (10^{-6} KM)
3. TIME (HRS.)
RANGE TO MM (10^{-6} KM)
C/O & REPAIR (6 HRS.)
SEPARATION
INJECTION THRU 1ST MC
PO
TIME (HRS.)
RANGE TO MM (10^{-6} KM)
C/O & REPAIR (18 HRS.)
SEPARATION
INJECTION
MSSR
TIME (HRS.)
RANGE TO MM (10^{-6} KM)
C/O & REPAIR (18 HRS.)
SEPARATION
GL
TIME (HRS.)
RANGE TO MM (10^{-6} KM)
C/O & REPAIR (12 HRS.)
SEPARATION
ACTIONS AND
MM
C/O PROBES; PERFORM STERILE REPAIRS IF NECESSARY; CALCULATE INJECTION MANEUVER; ALIGN PROBE AND MM INERTIAL PLATFORMS
ESTABLISH COMMUNICAT
LINK WITH PROBES; C/
SYSTEMS; PERFORM OPT
TRACKING; CALCULATE

TABLE 1 – MISSION SEQUENCE PLAN – PROBE PRE-ARRIVAL PHASE



9-A-3



DEGRADE OK
2.2.4
MARS ARRIVAL
(PERIAPSIS)
-24
-21
-18
-15
-12
-9
-6
-3
0
~.86
~.76
~.65
~.54
~.43
~.32
~.21
~.11
TELESCOPE PHOTOGRAPHY
ENTRY
-24
~.86
ENTRY
-20
~.71
ENTRY
-16
~.57
FINAL CORRECTION
ARRIVAL
-3.5
~.13
FINAL CORRECTION
ARRIVAL
-2.4
~.086
FINAL CORRECTION
-2.2
~.077
MARS PHOTOGRAPHS; RECEIVE & ANALYZE AD PROBE ATMOSPHERIC
LCULATE FINAL CORRECTIONS FOR PO, GL & MSSR PROBES; PERFORM OPTICAL AND
ACKING OF PO, GL & MSSR PROBES
PROGRAM TELESCOPE ENCOUNTER SEQUENCE

FUNCTIONS				
EARTH			PROVIDE CONSULTATION FOR PROBE REPAIRS IF ANOMALIES ARE DETECTED DURING C/O.	PROVIDE BACKUP AN COMPUTATIONAL CAP
COMMAND			THE CREW ISSUES COMMANDS TO: INITIATE PROBE SYSTEMS C/O: ALIGN PROBE AND MM INERTIAL PLATFORMS; PLACE PROBES IN INERTIAL HOLD ATTITUDE CONTROL MODE; INSERT INJECTION MANEUVER INFORMATION INTO PROBE MEMORIES	THE CREW ISSUES C HIGH GAIN ANTENNA STELLAR REFERENCE THE CREW ACTING I
CONTROL			CREW IN CONSULTATION WITH EARTH IF NECESSARY	CREW IN CONSULTAT
INFORMATION FLOW	INFORMATION FLOW INTO MM	ACQUIRED BY MM SENSORS	AD $\sim 10^2$ BPS FOR EACH 5 MIN C/O PER PROBE; $\sim 9 \times 10^4$ BITS TOTAL GL $\sim 10^3$ BPS FOR EACH 15 MIN C/O; $\sim 9 \times 10^5$ BITS TOTAL PO & MSSR $\sim 2 \times 10^3$ BPS FOR EACH 15 MIN C/O PER PROBE; $\sim 3.6 \times 10^6$ BITS TOTAL	PROBE SEPARATION THRU (TYPICAL) TIME DAT 0-1 HR 45 MIN ~ 1 HR 45 MIN-2 HR ~ 2 HR - 6 HR ~ 6 HR - 6 HR 15 MIN ~ 6 HR 15 MIN - 7 HR ~ 7 HR - 7 HR 15 MIN ~
		TRANSMITTED BY PROBES	PROBE ENGINEERING DATA ONLY AS INDICATED ABOVE	PROBE ENGINEERING
	INFORMATION FLOW FROM MM TO EARTH		TO BE SUPPLIED LATER	TO BE SUPPLIED LAT
	INFORMATION FLOW FROM EARTH TO MM		TO BE SUPPLIED LATER	TO BE SUPPLIED LAT
DECISIONS	AVAILABLE		NEED FOR PROBE REPAIRS (CREW IN CONSULTATION WITH EARTH IF NECESSARY)	CONTINUE WITH NOMINAL OR TERMINATE PROBE MI (CREW IN CONSULTATION EARTH IF NECESSARY)
	CRITERIA		PROBE ENGINEERING DATA	PROBE ENGINEERING
REAL-TIME OPTIONS			DELAY PROBE SEPARATION WITHIN TARGETING AND PROPULSION SYSTEM CONSTRAINTS; POSSIBLE CHOICE BETWEEN VARIOUS NOMINAL MISSIONS	
AREAS NEEDING FURTHER STUDY (SEE APPENDIX)			A. STERILE PROBE REPAIR B. PROBE REPAIR TIMES C. TRADEOFFS ASSOCIATED WITH DELAY OF PROBE INJECTIONS	A. OPTIMUM PROB D. A PRACTICAL

R ADDITIONAL ANALYSIS AND LITY FOR TARGETING & 1ST MCC			PROVIDE BACKUP AND/OR ADDITIONAL ANALYSIS AND COMPUTATIONAL CAPABILITY FOR POSSIBLE RETARGETING AND MCC	PROVI COMPUT PROFI
AMDS TO: SEQUENTIALLY SEPARATE PROBES FROM MM; DEPLOY OMNI AND ND SOLAR PANELS IF APPLICABLE; INITIATE PROBE SYSTEMS C/O; ACQUIRE ES; PERFORM 1ST MCC. THE INJECTION MANEUVER IS AUTOMATED WITH BACKUP CAPACITY			THE CREW ISSUES COMMANDS TO: PERFORM PROBE MCC; PERFORM POSSIBLE RETARGETING MANEUVERS	THE C ADJUST MANEUV
WITH EARTH IF NECESSARY.			CREW IN CONSULTATION WITH EARTH IF NECESSARY	SOME C ALWAYS
T MCC ATE (BPS) LOW -2×10^3 -2×10^3 LOW -2×10^3	FINAL MSSR & GL TARGETING PHOTOGRAPHS: 1 PHOTOGRAPH PER 1.5 HRS (22.5° OF PLANET ROTATION) = 16 PHOTOGRAPHS IN PARALLEL WITH AD & PO OPTICAL & RADAR TRACKING AT $\sim 10^2$ BPS PER PROBE	MARS PHOTOGRAPHY AT 1 PHOTOGRAPH PER 3 HRS (45° OF PLANET ROTATION) PROBE SEPARATION THRU 1ST MCC (TYPICAL) TIME — DATA RATE (BPS) 0-1 HR 45 MIN — ~ LOW 1 HR 45 MIN-2 HR — $\sim 10^2-2\times10^3$ 2 HR-6 HR — $\sim 10^2$ 6 HR-6 HR 15 MIN — $\sim 10^2-2\times10^3$ 6 HR 15 MIN-7 HR — ~ LOW 7 HR-7 HR 15 MIN — $\sim 10^2-2\times10^3$	AVERAGE OF $\sim 1.3\times10^8$ BITS PER PHOTOGRAPH FOR 8 PHOTOGRAPHS; $\sim 1\times10^9$ BITS TOTAL AVERAGE OF $\sim 2\times10^8$ BITS PER PHOTOGRAPH FOR 8 PHOTOGRAPHS; $\sim 1.6\times10^9$ BITS TOTAL AVERAGE OF $\sim 3.4\times10^8$ BITS PER PHOTOGRAPH FOR 8 PHOTOGRAPHS; $\sim 2.7\times10^9$ BITS TOTAL AVERAGE OF $\sim 7\times10^8$ BITS PER PHOTOGRAPH FOR 8 PHOTOGRAPHS; $\sim 5.6\times10^9$ BITS TOTAL AVERAGE OF $\sim 2.4\times10^9$ BITS PER PHOTOGRAPH FOR 8 PHOTOGRAPHS; $\sim 1.9\times10^{10}$ BITS TOTAL	
TA ONLY AS INDICATED ABOVE			PRIOR & SUBSEQUENT TO EACH MCC: AD $\sim 10^2$ BPS FOR 5 MIN GL $\sim 10^3$ BPS FOR 15 MIN PO & MSSR $\sim 2\times10^3$ BPS FOR 15 MIN PER PROBE	ATMOSP ~3 x I
			TO BE SUPPLIED LATER	TO BE
			TO BE SUPPLIED LATER	TO BE
EGRADE ON TH	LANDING SITE SELECTION (CREW IN CONSULTATION WITH EARTH)	CONTINUE WITH NOMINAL, DEGRADE OR TERMINATE PROBE MISSION (CREW IN CONSULTATION WITH EARTH IF NECESSARY)	CONTINUE WITH NOMINAL, DEGRADE OR TERMINATE PROBE MISSION (CREW IN CONSULTATION WITH EARTH IF NECESSARY)	CONTIN MISSIO
TA	INTERPRETATION OF ALL AVAILABLE MARS INFORMATION	PROBE ENGINEERING DATA	PROBE ENGINEERING DATA	
	VARIOUS NOMINAL MISSIONS FOR MSSR & GL DEPENDING ON LANDING SITE SELECTION	CHANGE OF INITIALLY CHOSEN MSSR & GL LANDING SITES	CHANGE INITIALLY CHOSEN NOMINAL PROBE MISSIONS BASED ON HIGHER RESOLUTION MARS PHOTOGRAPHS	1. CH ON 2. CH NE TE
INJECTION TIMES & CRITERIA FOR SPECIFICATION OF PROBE LAUNCH SEQUENCE ANGE SAFETY" PROCEDURE			A. TRADE OFFS IN CONNECTION WITH POSSIBLE CHANGES IN PROBE NOMINAL MISSIONS. B. DETERMINATION OF OPTIMUM MIDCOURSE CORRECTION STRATEGY C. TRANSMISSION OF PROBE TRACKING DATA TO EARTH FOR MIDCOURSE CORRECTION COMPUTATIONS	A. US B. CR

BACKUP AND/OR ADDITIONAL ANALYSIS AND TIONAL CAPABILITY TO DETERMINE ATMOSPHERIC AND FINAL PO, GL & MSSR CORRECTIONS		
V ISSUES COMMANDS TO: PERFORM FINAL PO, MSSR AND GL CORRECTIONS; FINAL PO, MSSR AND GL ATTITUDES; PERFORM PO PROPULSIVE DEBOOST R		
ERATIONS AUTOMATED WITH CREW OVERRIDE IN CONSULTATION WITH EARTH AVAILABLE		
~3.8 x 10^9 BITS; ~5 x 10^9 BITS; ~6.6 x 10^9 BITS; ~9.9 x 10^9 BITS; ~1.5 x 10^{10} BITS; ~2.6 x 10^{10} BITS; 5 x 10^{10} BITS (MARS FILLS PHOTOGRAPHIC PLATE)	2 x 10^{11} BITS 4 PHOTOGRAPHS	
RIC AND POSSIBLY GEODETIC DATA FROM 3 AD PROBES; BPS FOR 10 SEC EACH; ~9 x 10^4 BITS TOTAL PRIOR & SUBSEQUENT TO FINAL CORRECTIONS: GL ~10^3 BPS FOR 15 MIN PO & MSSR ~2 x 10^3 BPS FOR 15 MIN PER PROBE		
PPLIED LATER		
PPLIED LATER		
E WITH NOMINAL, DEGRADE OR TERMINATE PROBE (CREW IN CONSULTATION WITH EARTH IF NECESSARY)	THOSE REQUIRED IN PROGRAMMING TELESCOPE ENCOUNTER SEQUENCE (CREW IN CONSULTATION WITH EARTH IF NECESSARY)	
	INTERPRETATION OF ALL PREVIOUS MARS PHOTOGRAPHS	
IGE OF PO NOMINAL ORBITAL ELEMENTS BASED DATA OBTAINED BY AD PROBES. IGE IN MSSR AND GL NOMINAL LANDING SITES TO BY ALTERNATE SITES BASED ON HIGHER RESOLUTION SCOPE PHOTOGRAPHS.		
FOR PRE-ARRIVAL ATMOSPHERIC DATA. RESPONSE TIME CHARACTERISTICS IN CONNECTION WITH TELESCOPE OPERATION FOR "TARGETS OF OPPORTUNITY" PHOTOGRAPHY		

2.2.1 Phase Definition

The duration of this phase for the PO, MSSR, and GL probes consists of the time elapsed from their arrivals to the data rate break even point, at which the data rate capacities to the MM and the earth are equal. Transmission from the probes to the MM at greater ranges would result in a lower total data output for the overall mission.

Since the data rate break even point is independent of the probe transmission system, it is the same for all three of the probes.*[4] The break even range is 6.95×10^6 km. Using the constant MM velocity estimation the break even time is approximately +193 hours. The break even data rates are in general different depending on the probe transmission systems. However, in this particular case the rates for the PO, MSSR, and GL are all very close to 5×10^3 bps.

2.2.2 Nominal Mission Phase Description

2.2.2.1 Summary

In this phase the PO, MSSR, and GL probes arrive at their previously determined target localities. As soon as line

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*See Appendix (2.2.1 - A)

of sight constraints permit, the crew remotely checks out and locates the probes. Operations prior to RV liftoff are primarily keyed to the acquisition of visual surface data to be used for both post-encounter long term analysis and as a means of optimizing the selection of localities for surface soil sampling. The RV flight results in the delivery of two pounds of payload, consisting of soil and aerosol samples, and color photography exposures, to the MM several minutes after MM periapsis passage. These data are subsequently complemented by the direct readout transmission to the MM of 158 PO photographs of about 8 m resolution, each covering a 40 km x 40 km surface area. Slightly overlapping direct PO readout operations is the transmission of visual and non-visual surface data from the MSSR and GL probes to the MM. Transmission of surface data from these probes continues in parallel with buffered PO photo transmission for the remainder of the phase. This final portion of the phase also includes operations using the PO and surface probes as data storage and relay stations to increase data output and provide alternate data flow paths if necessary. This operational mode could provide an additional 38 PO photographs if desired, thus enabling acquisition of a total of 193.

The principal elements involved in this phase are: the PO, MSSR, and GL probes; the MM; the crew; and the earth-based control center. The crew controls the various operations in consultation with earth when necessary. Early in the phase consultation is limited or nonexistent due to the communication time delay, thus placing control responsibility on the crew complemented by an appropriate degree of automation.

Communication between the probes and the MM is restricted to transmission over six discrete bandwidths for each probe. The same bandwidths are used for both surface probes. The discrete bandwidth magnitudes are dominated by the required transmission of visual data within system, occultation, and operational time constraints while non-visual data requirements exert a relatively minor influence on the information rates. In the latter portion of the phase, simultaneous transmission to the MM by the three probes is performed using sufficiently separated carrier frequencies. Furthermore, it is assumed that sufficient bandwidth is available for the earth to provide effective consultation service to the crew.

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*In terms of number of photographs this is equivalent to a single Lunar Orbiter mission.

The crew functions in a variety of modes, including the interpretation of facsimile panoramas and real time surface TV observation in selecting promising surface soil sampling localities. The early bioanalysis of a fresh surface sample by a crew member is carried out under essentially laboratory conditions.* The primary functions of the earth are to provide consultation and analytical services and backup or additional computational capacity.

2.2.2.2 Subphase Descriptions

2.2.2.2.1 Probe Arrivals through Checkouts

The first probe to arrive is the PO which deboosts approximately over the North Pole into a 300 km circular polar orbit at -3.5 hours as shown in Figure 1.**[10] Line of sight from the MM to the PO is interrupted immediately after the retrograde maneuver and the PO reappears over the South Pole about 55 minutes later at -2 hours 35 minutes.***[11,12] At the time of appearance over the South Pole PO tracking and systems checkout are initiated. The former provides data for preliminary orbit determination and the latter, information needed for possible remedial action in the event of a probe malfunction. A data rate of about 10^3 bps is estimated as being adequate to meet the requirements of this operation.[13] Tracking and checkout are continued until line of sight is again interrupted at -1 hour 40 minutes. Immediately prior to loss of line of sight the crew sends a command to the PO describing the sequence of photographs to be taken on the next passage over the sunlit face of the planet. This is necessary because real time control of the first photographic sequence would conflict with crew-surface probe operations.

The MSSR probe touches down at a minimum feasible time prior to periapsis of -2 hours 24 minutes, which precedes termination of PO tracking (and the photographic command) by 44 minutes. Consideration of the mission profile for the surface probes presented in Figure 2 shows why the overlap with crew-PO operations does not generate an operations

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*The division between crew and automated functions has not been determined.

**See Appendix (2.2.2.2.1 - A)

***See Appendix (2.2.2.2.1 - B)

conflict. The trajectory for the surface probes results in a worst case landing location of about 11 degrees beyond the planetary limb, thus requiring a maximum of approximately 44 minutes of planet rotation for the surface probes to rotate into line of sight with the MM.*[14,15] Therefore, there are no communications between these probes and the MM for the first 44 minutes after landing.**

As soon as communications with the MM are established, the crew initiates MSSR checkout, which continues for an estimated 15 minutes at a data rate of 2×10^3 bps. Initiation of the checkout operation is timed to occur when the MM-PO line of sight is interrupted, at about -1 hour 40 minutes. Similarly, at termination of MSSR checkout the same procedure is initiated for the GL and is performed for the same duration at the lower data rate of 1×10^3 bps. Immediately prior to the MSSR-GL communications switchover, the crew sends a command to the MSSR, initiating those surface sample acquisition operations which do not require a facsimile panorama of the surrounding terrain. Typical operations are drilling to obtain sub-surface soil samples and aerosol sampling of the atmosphere.[16] This is suggested because of the close proximity to the morning terminator and the resulting poor lighting conditions for the acquisition of visual facsimile information. After the communications switchover, drilling and aerosol sampling are performed automatically and in parallel with GL checkout. The crew uses surface probe checkout data to verify the integrity of probe systems and commands a switch to an alternate mode if a malfunction is detected.

2.2.2.2.2 Pre-RV Liftoff Operations

After the surface probe checkouts a nominal time of about 1/2 hour is allowed for the probes to rotate to a sun angle where the lighting conditions for obtaining facsimile panoramas are marginally acceptable. In the case of the MSSR the panorama is initiated at -55 minutes at a sun elevation angle of about 8° with one minute being allocated for picture transmission. For a 360° x 60° panorama with 6000 x 1000 lines

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*Based on entry at 222 km altitude with a flight path angle of 18.1°; VM-8 atmosphere; and for both landing probes $\frac{m}{C_d A} = .8$.

**See Appendix (2.2.2.2.1 - C)

and assuming 6 bits per dot for the gray scale, a data rate of 6×10^5 bps is required for the one-minute transmission.* Once the MSSR terrain panorama is aboard the MM, the crew analyzes these visual data with the objective of optimizing surface soil sample acquisition.

At about -45 minutes the PO reappears over the South Pole and begins its previously commanded and stored automatic photographic sequence. MM panoramic and multi-spectral surface and cloud photography is initiated, with the panoramic photography continuing until terminator crossing (-90 sec) and multi-spectral imaging data being acquired through +45 minutes. Panoramic photography should provide 2.5×10^{13} bits over a period of about 45 minutes while multi-spectral imaging should yield 10^{11} bits in approximately 90 minutes centered at periapsis.[6] Since these photographic operations occur during a period of high probe-MM activity, they are fully automatic, requiring only activation. The operation of MM non-imaging instruments which produce an estimated 10^9 bits of data on the martian surface, atmosphere, and magnetic and radiation fields is carried out in the -45 minute to +45 minute period.**

The facsimile terrain analysis which is conducted by the crew in parallel with the automated panoramic and multi-spectral photography is complemented by the acquisition of a second terrain panorama (same facsimile characteristics and lighting conditions) from the GL at about -41 minutes.*** Immediately subsequent to acquisition of the GL terrain panorama, two 180° (i.e., horizon to horizon) facsimile scans separated by 90 degrees in azimuth are also transmitted to the MM. These visual data are used to complement the information obtained from the flight of the sounding rocket. An allocation of ten minutes for automatic sounding rocket set-up and subsequent flight is made. Since the sounding rocket has line-of-sight contact with the MM and the surface located GL, simultaneous transmission via omni-antennas of its data to both receivers provides redundancy of data reception. A data transmission time of about two minutes results in a data rate requirement of 2×10^2 bps.[17]

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*See Appendix (2.2.2.2.2 - A)

**See Appendix (2.2.2.2.2 - B)

***See Appendix (2.2.2.2.2 - C)

Terrain panorama analysis by the crew continues in parallel with the automated sounding rocket operations and provides the basis for a decision as to the deployment locations of the surface soil sampling devices.* Having made the instrument deployment decisions, the crew transmits commands first to the MSSR at about -21 minutes and then to the GL at -20 minutes, the former command initiating the surface soil sampling operations. Included in this command (and temporarily inhibited) are location assignments of geophysical instruments to be deployed subsequent to RV liftoff. About 9.5 minutes are allocated for the gathering and transfer of the surface soil samples to the RV payload. Since it is desirable to have diagnostic information in the event of a malfunction of the surface soil sampling apparatus, it is necessary to observe the sampling operations in real time via a TV link.** The TV system would also serve as a backup to the facsimile camera in the event the martian surface is dynamic in nature.***

After the soil samples are transferred to the RV payload and prior to liftoff, a series of 35mm color photos of the surrounding terrain are obtained and included in the payload to be returned to the MM. Acquisition of these color photos is delayed until immediately before launch in order to take advantage of the steadily increasing sun elevation angle, which is about 18° at the time of photography.

2.2.2.2.3 RV Flight

The flight profile of the RV is illustrated in Figure 3.# Liftoff of the vehicle occurs at about -11.5 minutes with first stage burnout estimated at -6 minutes, while burn of the second stage is estimated to terminate at -1.5 minutes. Third stage ignition occurs at -.5 minutes after a coast phase of about 1 minute, with rendezvous occurring at +5 minutes.##

The liftoff operation is observed by the crew using the TV link.### After liftoff the cameras continue to function in a tracking theodolite fashion. Transmission and reception of

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*See Appendix (2.2.2.2.2 - D)

**See Appendix (2.2.2.2.2 - E)

***High velocity movement of any kind, e.g., dust storms.

#See Appendix (2.2.2.2.3 - A)

##See Appendix (2.2.2.2.3 - B)

###The cameras are protected from fire-in-the-hole thermal effects and mounted for vibration isolation to minimize image distortion.

the liftoff and tracking images by omni-antennas is carried out at the prevailing short range. Starting at liftoff and in parallel with the TV operations the MM high gain antenna tracks the ascending RV throughout its flight. This is supplemented by optical tracking when the vehicle emerges from its sub-resolution state at about the time of third stage ignition, one minute after MM terminator crossing. Thus, there is no conflict with the preprogrammed telescopic photographic sequence described under 2.1.2.2.4. The RV should be clearly visible since it is sunlit and viewed against a black background, facilitating the terminal rendezvous which is concluded at +5 minutes. In order to maximize the chance of life detection and characterization, the crew begins biological, geochemical, and geophysical analyses of the soil samples as soon as their transfer to the MM is completed.*

2.2.2.2.4 Direct PO Photographic Readout

The duration of this subphase is 15 hours and 21 minutes, during which PO photos of Lunar Orbiter quality and 8 m resolution each covering an area of 40 km x 40 km are directly read out, compressed and coded by a factor of four, and transmitted to the MM at a fixed rate of 8.3×10^5 bps per readout system.**[18,19,20,21] Three photo readout systems are used in parallel, thus increasing the data rate to 2.5×10^6 bps. Operation in this mode continues until about +8 hours 54 minutes, when it is no longer possible to sustain the information rate without incurring photo quality degradation through reduction of signal-to-noise ratio. At this time one of the systems is switched off and parallel operation of two readout systems continues for about two hours longer until the signal-to-noise ratio constraint is again violated at about +10 hours 54 minutes. A second system is turned off, and in the remaining 4 hours and 30 minutes of the subphase a single photo readout system is in operation.

The PO has line-of-sight contact with the MM for one-half of the subphase duration, with about ten percent of this time unavailable for transmission for operational reasons. Under this transmission time constraint 120 photos are obtained during triple readout system operation, 18 during double operation, and 20 for the single readout system period, resulting in a total of 158 photos with the area coverage and resolution mentioned above.***

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*See Appendix (2.2.2.2.3 - C and D)

**See Appendix (2.2.2.2.4 - A)

***See Appendix (2.2.2.2.4 - B and C)

While the PO is acquiring and intermittently transmitting photos to the MM, the two surface probes obtain additional facsimile panoramas and initial geophysics data, recording them in interim on-board storage for transmission to the MM when line-of-sight contact is reestablished. The data storage system has been sized to accommodate a maximum of 12 facsimile panoramas resulting in a storage requirement of 4.3×10^8 bits.[1] Line-of-sight contact with the MM is reestablished at +10 hours 30 minutes and +10 hours 48 minutes for the MSSR and GL, respectively. At +10 hours 30 minutes the range is sufficiently great that the MM high gain antenna beam width includes the entire planet and can therefore "listen" to the PO, MSSR, and GL probes simultaneously, transmitting on appropriately separated carrier frequencies (i.e., $\sim$5 Mc).

Starting from the time the line of sight is about five degrees above the horizon, 5.5 hours is allocated for transmission of the data stored in each surface probe, resulting in a data rate of about 2.2×10^4 bps to the MM. The initial geophysics data are visually displayed to the crew as they are received. Based on these data the crew determines an appropriate long duration sampling rate for each geophysical instrument. The estimated total rate for the surface probe geophysics package which consists of several instruments is 300 bps. Immediately after the initial surface probe transmission period the crew commands the geophysics instruments to commence sampling at their long duration rates. The geophysics experiments are assumed to broadcast at a total rate of 300 bps for the remainder of the phase. During line-of-sight availability they transmit directly to the MM, and while occulted, data are recorded in on-board storage. Furthermore, enough time after rendezvous will have elapsed to make preliminary soil sample analysis results available for use in meaningful crew planning of surface geophysics experiments.

The 5.5-hour period specified for depletion of surface probe storages extends into the next subphase.

2.2.2.2.5 Pre-Break Even Point Operations

This final subphase starts at +15 hours 21 minutes and terminates at approximately +8 days. It is nominally characterized by buffered PO photo transmission in parallel with transmission of visual and non-visual surface data from the surface probes. Direct transmission from the three probes to the MM is intermittent due to the periodic interruption of line of sight. However, there are several nominal and contingency operational modes using the PO and surface probes as data storage and relay stations. Implementation of these schemes partially overcomes occultation constraints and provides an alternate path for surface data to be transmitted to the MM in the event of a surface probe communication subsystem malfunction.

The PO data storage capacity of 4.3×10^8 bits is used to store 1.4 compressed and coded (factor of 4) photos in preparation for transmission to the MM.* The buffering mode permits transmission of photos to the MM at lower information rates than those generated by the fixed rate direct readout systems, thus allowing Lunar Orbiter photo quality to be maintained. The first of the reduced data rates is determined by assuming PO storage to be emptied over a period of 45 minutes resulting in a transmission rate of 1.85×10^5 bps until +30 hours 6 minutes, beyond which time continued transmission at this rate would result in signal-to-noise ratio degradation. The rate is then reduced to 10^4 bps for about 100 hours until the signal-to-noise ratio constraint is again violated. Since the number of discrete transmission bandwidths is limited, the data rate must be prematurely reduced to the break even rate of 5×10^3 bps for the remainder of the subphase, about 63 hours.

Line-of-sight contact with the MM is available for one-half of the subphase but for operational reasons 18 percent of that time cannot be used for communications, resulting in a total transmission time of about 73 hours. Transmission at the first rate provides 13 photos, at the intermediate rate, five, and at the final rate, one, for a total of 19 obtained through buffered transmission. The combined photographic output of both the direct and buffered transmission modes is, therefore, 177 images of Lunar Orbiter quality with the previously mentioned area coverage and resolution. Additionally, during the buffered mode of data communication a total of 2.34×10^8 bits of non-visual information from the PO orbital geophysics package is transmitted to the MM.

While the PO is tranmsitting photos to the MM from interim on-board storage, PO-surface probe operations are also performed. This is possible due to the estimated minimum availability of 20 minutes per day of line-of-sight contact between each surface probe and the PO as illustrated in Figure 4. In this mode the PO and surface probes act as data storage and relay stations providing additional data transmission paths to the MM. The 5.5-hour duration specified for depletion of surface probe storage is based on the need for that storage to be available for reception of PO photographic data when line-of-sight contact between the probes is established. Nominally, the

*PO storage capacity is matched to those of the MSSR and GL. Storage size is a conservative estimate of 1975 erasable magnetic tape capability.

PO uses the first ten-minute line-of-sight period to fill surface probe storage with 1.4 compressed and coded PO photos by transmission through an omni-antenna. The recorded photos are relayed to the MM in the 5.5-hour period between termination of surface probe-PO and surface probe-MM lines of sight. This mode can be used in reverse as a contingency plan in the event of certain surface probe communication system failures.* The line-of-sight period can be used to unload surface probe storage via transmission over an omni-antenna at 6×10^5 bps into interim PO storage followed by relay to the MM at the expense of 1.4 PO photos per surface probe storage relay.

After the surface probes rotate out of line-of-sight contact with the MM, data acquired from all sources are recorded in on-board storage for subsequent transmission to the MM. During this period of occultation and corresponding sunlight the geophysics experiments sampling at the specified rate require only three percent of the surface probe storage capacity. About six hours subsequent to MM line-of-sight termination another ten-minute period of communication with the PO allows the acquisition of additional PO photos via surface probe relay. However, since there are six hours of sunlight prior and subsequent to the second daily PO-surface probe line-of-sight period, the composition of surface probe storage at reestablishment of the uplink is uncertain and will depend on real time planning by the crew. At uplink acquisition of the MM, the geophysics experiments are automatically switched to the direct transmission mode and storage depletion at 2.2×10^4 bps is automatically initiated.

The portion of the subphase at this data rate continues until the signal-to-noise ratio constraint is violated at about +84 hours, at which time the rate of depletion of surface probe storage will be reduced by a factor of two. This provides for storage depletion over the full 11-hour period of line-of-sight contact at a data rate of 1.1×10^4 bps, with signal-to-noise degradation at about +120 hours.

During the first of the specified periods 1.4 PO photos per surface probe are relayed to the MM for each dark side ten-minute period of line-of-sight contact between the PO and surface probes. Since the composition of surface probe storage resulting from sunlight operations is uncertain, only one PO photo is transmitted into each of the surface probe storages during the other daily line-of-sight period.

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*For example, a high gain antenna gimbal mechanism failure.

These operations result in the relaying to the MM via the MSSR and GL of 12 additional PO photos supplemented by the acquisition of 9 x 10^8 bits of visual and non-visual surface data.

During the second period dark side transmission of PO photos to surface probe storage is suspended since, due to the specified data rate, the entire MM line-of-sight period is needed to empty storage. However, one photo per surface probe is recorded in on-board storage for subsequent relay during the ten-minute line-of-sight period on the sunlit side of the planet. The data output for this period is four additional PO photos and about 4.25 x 10^8 bits of visual and non-visual surface data.

The data rate is subsequently stepped down to 8 x 10^3 bps and continues intermittently for a duration of 21 hours when at +141 hours the signal-to-noise ratio constraint is violated, forcing a premature reduction to the break even value of 5 x 10^3 bps. As before, this is due to the specification of a maximum number of six discrete transmission bandwidths. The periodic transmission at 8 x 10^3 bps over the indicated duration results in a total of 5.8 x 10^8 bits of information. Intermittent transmission at the break even rate until +193 hours results in about 8.3 x 10^8 bits of data. The total of 14.1 x 10^8 bits acquired during these last two transmission periods can consist of a number of types of data. For example, it could be comprised of four additional PO photos supplemented by 2.1 x 10^8 bits of visual and non-visual surface data. The actual configuration of this final block of Mars encounter data is determined by the crew.*

At arrival at the break even point the crew commands the probes to acquire the earth for long duration data transmission for the remainder of their lifetimes. The crew subsequently develops a priority listing of data to be transmitted to earth from the MM.

E. M. Grenning

1014-EMG-jdc E. M. Grenning

Attachment
Figures 1 - 4

*See Appendix (2.2.2.2.5 - A)

2.2 PROBE POST ARRIVAL PHASE		2.2.1 PROBE ARRIVALS THROUGH CHECKOUTS	2.2.2 PRE-RV LIFTOFF OPERATIONS
MM	TIME (HRS:MIN)	-3:30 -2:30 -1:30 4 TELESCOPE PHOTOGRAPHS (15 MIN) PREPROGRAMMED TELESCOPE PHOTOGRAPHIC SEQUENCE (1 HR. 35 MIN.)	-1:10 -0:55 -0:40 -0:25 PREPROGRAMMED TELESCOPE PHOTOGRAPHIC SEQUENCE (59 MIN.) PANORAMIC & MULTI-SPECTRAL PHOTOGRAPHY; NON-VISUAL EXPERIMENTS (34 MIN.) TERRAIN ANALYSIS; SURFACE SOIL SAMPLING & GEOPHYSICS INSTRUMENT DEPLOYMENT DECISIONS (33 MIN.)
	RANGE TO PLANET (10^{-6} KM)	~.126 ~.09	~.042 ~.024
PO	TIME (HRS:MIN)	-3:30 ARRIVAL OCCULTED (55 MIN.) -2:35 C/O & TRACKING (55 MIN.) -1:40 OCCULTED (30 MIN)	OCCULTED (25 MIN.) -0:45 START AUTOMATIC PHOTOGRAPHIC SEQUENCE AUTOMATIC PHOTOGRAPHIC SEQUENCE (34 MIN.)
MSSR	TIME (HRS:MIN)	ARRIVAL -2:24 OCCULTED (44 MIN.) -1:40 AM TERMINATOR CROSSING -1:25 C/O & TRACKING (15 MIN.)	REAL TIME TV OBSERVATION (44 MIN.) -0:55 TERRAIN PANORAMA (1 MIN.) SURFACE S[...] SAMPLE GATHERING (9.5 MIN.)
GL	TIME (HRS:MIN)	ARRIVAL -2:09 OCCULTED (44 MIN.) -1:25 AM TERMINATOR CROSSING C/O & TRACKING (15 MIN.)	REAL TIME TV OBSERVATION (30 MI[...] -0:41 TERRAIN & SKY PANORAMAS (3 MIN.) SOUNDING ROCKET SET UP & FLIGHT (10 MIN) -0:[...] DEPLOY GEOPHYSIC[...] INSTRUMEN[...]
ACTIONS AND FUNCTIONS	MM	C/O PROBE SUBSYSTEMS; INITIAL RADAR TRACKING; INITIATE PO, GL& MSSR LANDING SITE AND ORBIT DETERMINATION; PERFORM PREPROGRAMMED TELESCOPE PHOTOGRAPHIC SEQUENCE; PO AUTOMATIC PHOTOGRAPHIC SEQUENCE COMMAND.	PERFORM PREPROGRAMMED TELESCOPE PHOTOGRAPHIC SEQUENCE: TERRAIN ANALYSIS & DECISION MAKING FOR SURFACE SAMPLE GATHERING & GEO-PHYSICAL INSTRUMENT DEPLOYMENT; OBSERVE SURFACE IN REAL TIME VIA TV LINK; PERFORM PANORAMIC & MULTI-SPECTRAL PHOTOGRAPHY; PERFORM NON-VISUAL EXPERIMENTS; OBSERVE SURFACE SOIL SAMPLING VIA TV LIN[...]
	EARTH	TRACKS MM; PROVIDE BACKUP AND/OR ADDITIONAL COMPUTATIONAL CAPACITY; LIMITED ANALYSIS AND CONSULTATION SERVICES.	TRACKS MM

BLE 2 - MISSION SEQUENCE PLAN - PROBE POST ARRIVA

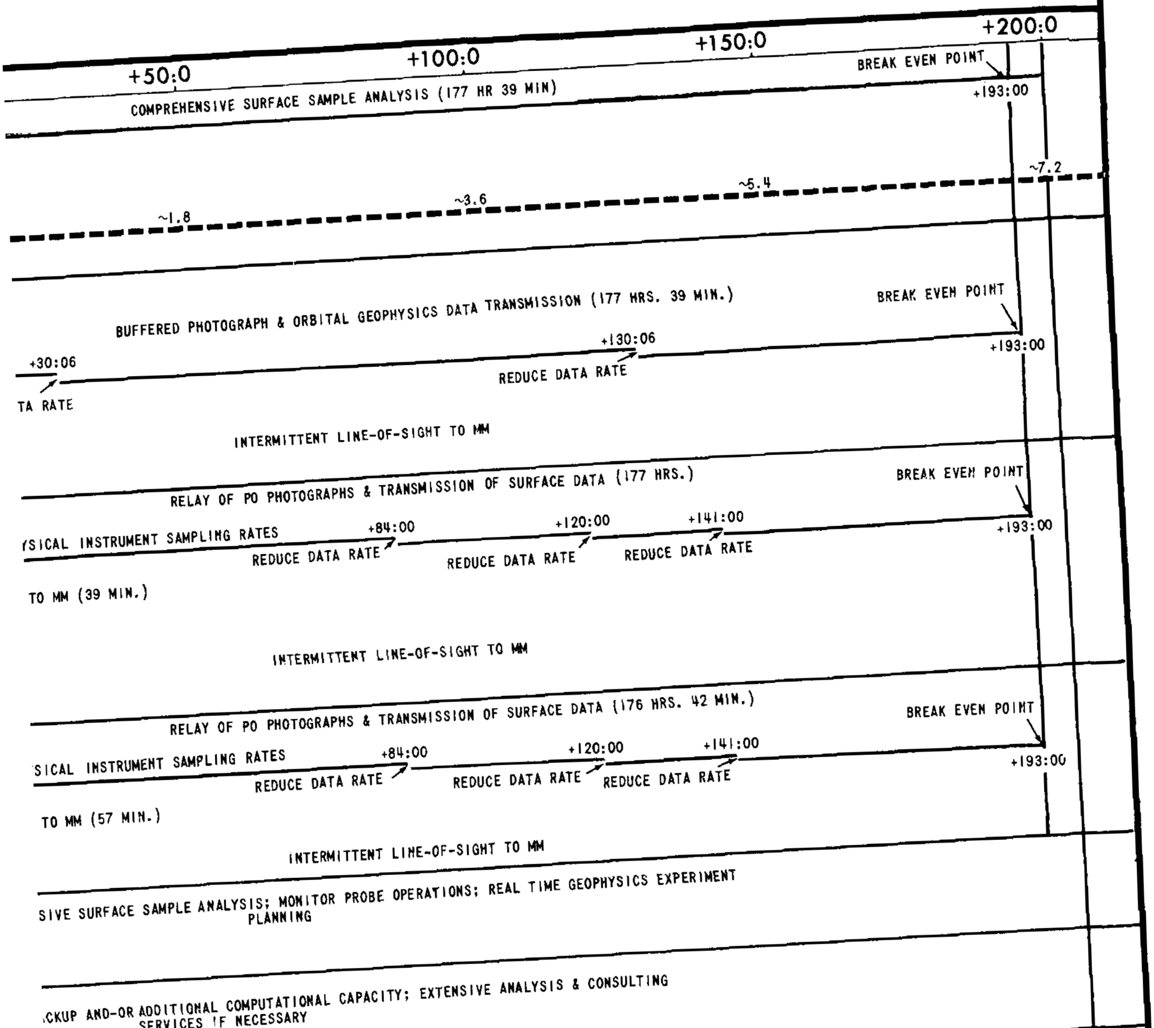
21-2

	2.2.3 RV FLIGHT	2.2.4 DIRECT PO PHOTOGRAPHIC READ OUT	
	0:11 -0:10 -0:5 -0:0	+0:5 +5:0 +10:0	+15:21
	PREPROGRAMED TELESCOPE PHOTOGRAPHIC SEQUENCE & PANORAMIC PHOTOGRAPHY (10 MIN.) MM TERMINATOR CROSSING MULTI-SPECTRAL PHOTOGRAPHY & NON-VISUAL EXPERIMENTS (16 MIN.) RV RADAR TRACKING (10 MIN.) RV RADAR & OPTICAL TRACKING (6 MIN.)	PRELIMINARY SURFACE SAMPLE ANALYSIS (15 HR. 16 MIN.) MULTI-SPECTRAL PHOTOGRAPHY & NON-VISUAL EXPERIMENTS (40 MIN.)	
	~.007	~.180 ~.360	~.552
	AUTOMATIC PHOTOGRAPHIC SEQUENCE (16 MIN.) +C:10	3 READ OUT SYSTEMS (8 HRS. 44 MIN.) +8:54 2 READ OUT SYSTEMS (2 HRS.) +10:54 1 READ OUT SYSTEM (4 HRS. 27 MIN.)	REDUCI
		INTERMITTENT LINE-OF-SIGHT TO MM	
DIL	DEPLOY GEOPHYSICS INSTRUMENTS ACQUISITION & STORAGE OF SURFACE DATA (15 MIN.) 1ST STAGE BURN (5 MIN.) 2ND STAGE BURN (5 MIN.) 3RD STAGE BURN (5 MIN.) RV LIFTOFF 2ND STAGE IGNITION COAST (1 MIN.) 3RD STAGE IGNITION LIFTOFF TV & THEODOLITE TV TRACKING (6 MIN.)	ACQUISITION & STORAGE OF SURFACE DATA (10 HRS. 25 MIN.) +10:30 LINE-OF-SIGHT TO MM TRANSMISSION TO MM (4 HR 51 MIN.) RENDEZVOUS WITH MM	ADJUST GEI +16:00 TRANSMISSI
.) 5			
S	ACQUISITION & STORAGE OF SURFACE DATA (16 MIN.)	ACQUISITION & STORAGE OF SURFACE DATA (10 HRS. 43 MIN.) +10:48 LINE-OF-SIGHT TO MM TRANSMISSION TO MM (4 HRS. 33 MIN.)	ADJUST GEOP +16:18 TRANSMISSI(
	PERFORM PREPROGRAMMED TELESCOPE PHOTOGRAPHIC SEQUENCE; OBSERVE RV LIFTOFF & EARLY RV FLIGHT IN REAL TIME VIA TV LINK; PERFORM PANORAMIC & MULTI-SPECTRAL PHOTOGRAPHY; PERFORM NON-VISUAL EXPERIMENTS; OPTICAL & RADAR TRACKING OF RV; TERMINAL RENDEZVOUS & TRANSFER SURFACE SAMPLES TO MM	ACQUIRE COMMUNICATION LINKS WITH PROBES; REAL TIME PO PHOTOGRAPHIC PLANNING; PRELIMINARY SURFACE SAMPLE ANALYSIS, DETERMINE GEOPHYSICAL INSTRUMENT SAMPLING RATES	COMPREHE
	TRACKS MM	TRACKS MM; PROVIDES BACKUP AND/OR ADDITIONAL COMPUTATIONAL CAPACITY; ANALYSIS AND CONSULTATION SERVICES	TRACKS MM; E

PHASE

2.2.5

PRE-BREAK EVEN POINT OPERATIONS



COMMAND		THE CREW ISSUES COMMANDS TO: PROVIDE PO AUTOMATIC PHOTOGRAPHIC SEQUENCE FOR SECOND SUNLIT PASS; INITIATE MSSR NON-VISUAL SURFACE SAMPLING, E.G., DRILL AND AEROSOL.	THE CREW ISSUES COMMANDS TO: ACQUIRE GL AND MSSR TERRAIN PANORA INITIATE MSSR SURFACE SOIL SAMPLING; DEPLOY GL AND MSSR GEOPHYSIC INSTRUMENTS TO BE IMPLEMENTED AFTER RV LIFT OFF; START MM PANORAM AND MULTI-SPECTRAL IMAGING DEVICES; START MM NON-VISUAL EXPERIMEN COMMENCE RV COUNT DOWN.
CONTROL		CREW WITH LIMITED EARTH BACKUP	CREW
INFORMATION FLOW	INFORMATION FLOW INTO MM — ACQUIRED BY MM SENSORS	4 TELESCOPE PHOTOGRAPHS @ 5×10^{10} BITS PER PHOTOGRAPH; $\sim2\times10^{11}$ BITS TOTAL AVERAGE OF 1 TELESCOPE PHOTOGRAPH PER 2.5 MIN @ 5×10^{10} BITS PER PHOTOGRAPH; $\sim1.9\times10^{12}$ BITS TOTAL PO C/O & TRACKING $\sim10^3$ BPS MSSR C/O & TRACKING $\sim2\times10^3$ BPS GL C/O & TRACKING $\sim10^3$ BPS	PANORAMIC PHOTOGRAPHY $\sim1.9\times10^{13}$ BITS; MULTI-SPECTRAL PHOTOGRAPHY $\sim3.7\times10^{10}$ BITS; NON-VISUAL DATA $\sim3.7\times10^8$ BITS AVERAGE OF 1 TELESCOPE PHOTOGRAPH PER 2.5 MIN. @ 5×10^{10} BITS PER PHOTOGRAPH; $\sim1.2\times10^{12}$ BITS TOTAL
	INFORMATION FLOW INTO MM — TRANSMITTED BY PROBES	PROBE ENGINEERING DATA ONLY AS INDICATED ABOVE	MSSR TERRAIN PANORAMA: $\sim3.6\times10^7$ BITS IN 1 MIN. $\sim6\times10^5$ BPS GL TERRAIN & SKY PANORAMAS: $\sim7.2\times10^7$ BITS IN 2 MIN $\sim6\times10^5$ BPS SOUNDING ROCKET DA 2.4×10^4 BITS FOR ~2 MIN. $\sim2\times10^5$ BPS 3.1×10^7 BPS GL REAL TIME TV OBSERVATION OF SURFACE 3.1×10^7 BPS MSSR REAL TIME TV OBSERVATION OF SURFACE
	INFORMATION FLOW FROM MM TO EARTH	TO BE SUPPLIED LATER	TO BE SUPPLIED LATER
	INFORMATION FLOW FROM EARTH TO MM	TO BE SUPPLIED LATER	TO BE SUPPLIED LATER
DECISIONS	AVAILABLE	CONTINUE WITH NOMINAL, DEGRADE OR ABORT IN SITU PROBE OPERATIONS (CREW IN LIMITED CONSULTATION WITH EARTH)	DEPLOYMENT LOCATIONS OF SURFACE SAMPLING EQUIPMENT & GEOPHYSICS INSTRUMENTS (CREW) DEGRADE OR ABORT SURFACE SOIL SAMPLING OPERATIONS (CREW)
	CRITERIA	PROBE ENGINEERING DATA	TERRAIN PANORAMAS AND REAL TIME TV OBSERVATION OF SURFACE
REAL TIME OPTIONS		TELESCOPE TARGETS OF OPPORTUNITY AS THEY OCCUR VARIOUS AUTOMATIC PO PHOTOGRAPHIC SEQUENCES FOR 2ND SUNLIT PASS	POSSIBLE TELESCOPE TARGETS OF OPPORTUNITY AS THEY OCCURR SACRIFICE TERRAIN ANALYSIS TIME TO ACQUIRE PANORAMAS AT HIGHER SUN ANGLE
AREAS NEEDING FURTHER STUDY (SEE APPENDIX)		B. FEASIBILITY OF PO AERODYNAMIC DEBOOST MANEUVER. C. HAZARDOUS MSSR AND GL LANDING CONDITIONS	B. RANGE AT ACTIVATION AND DEGREE OF AUTOMATION OF NON-VISUAL EXPERIMENTS C. POSSIBLE ADVANTAGES OF OBTAINING 2 PANORAMAS: ONE FROM MSS AND ONE FROM GL UNDER SAME LIGHTING CONDITIONS D. TERRAIN ANALYSIS AND DECISION MAKING THAT CAN BE PERFORMED BY THE CREW IN A GIVEN AMOUNT OF TIME.

THE CREW ISSUES COMMANDS TO; STOP MM PANORAMIC AND PREPROGRAMMED TELESCOPIC PHOTOGRAPHY; GUIDE THIRD STAGE RV FLIGHT AND TERMINAL RENDEZVOUS. RV LIFT OFF THROUGH SECOND STAGE BURN OUT IS AUTOMATED WITH CREW ACTING IN A BACKUP CAPACITY	THE CREW ISSUES COMMANDS TO: STOP MM MULTI-SPECTRAL PHOTOGRAPHY & NON-VISUAL EXPERIMENTS; PROVIDE REAL TIME PO PHOTOGRAPHIC PLANNING	THE CREW RATES TO RATES FO RECEPTIO MENT CON
HIGH DEGREE OF AUTOMATION WITH CREW INTERMITTENTLY IN LOOP	SOME AUTOMATION WITH CREW IN LOOP AT ALL TIMES	SOME AU
PANORAMIC PHOTOGRAPHY ~6 x 10^{12} BITS; AVERAGE OF 1 TELESCOPE PHOTOGRAPH PER 2.5 MIN @ 5 X 10^{10} BITS PER PHOTOGRAPH ~2 x 10^{11} BITS 2 LB SURFACE SAMPLE MULTI-SPECTRAL PHOTOGRAPHY ~1.8 x 10^{10} BITS; NON-VISUAL DATA ~1.8 x 10^8 BITS	MULTI-SPECTRAL PHOTOGRAPHY ~4.5 x 10^{10} BITS; NON-VISUAL DATA ~4.5 x 10^8 BITS	DATA RE
REAL TIME LIFTOFF TV & THEODELITE TV TRACKING ~3.1 x 10^7 BPS	9.7 MSSR TERRAIN PANORAMAS ~3.5 x 10^8 BITS MSSR GEOPHYSICS INSTRUMENT DATA ~3.2 x 10^7 BITS 8.9 GL TERRAIN PANORAMAS ~3.2x10^8 BITS; GL GEOPHYSICS INSTRUMENT DATA ~2.9x10^7 BITS 18 PO PHOTOGRAPHS ~2.1 x 10^{10} BITS 120 PO PHOTOGRAPHS ~1.4 x 10^{11} BITS 20 PO PHOTOGRAPHS ~2.4 x 10^{10} BITS	2.1 GL T GL GEOPH 1.3 MSSR MSSR GEO 19 PO PH GL & MSSI & 1.3 x
TO BE SUPPLIED LATER	TO BE SUPPLIED LATER	TO BE SUP
TO BE SUPPLIED LATER	TO BE SUPPLIED LATER	TO BE SUP
THOSE REQUIRED IN PERFORMING TERMINAL RENDEZVOUS MANEUVERS (CREW)	THOSE REQUIRED FOR REAL TIME PO PHOTOGRAPHIC PLANNING (CREW IN CONSULTATION WITH EARTH IF NECESSARY)	1. APPR 2. PRIO
OPTICAL AND RADAR TRACKING INFORMATION	PREVIOUS TELESCOPE & PO PHOTOGRAPHS	1. EXIST 2. DATA
	RELAY DATA VIA PO FOR CERTAIN MSSR OR GL COMMUNICATION SYSTEM FAILURES VARIOUS CONTIGUOUS PO PHOTOGRAPHIC SEQUENCES	RELAY
A. NON-COPLANAR RV - MM RENDEZVOUS C. SURFACE SAMPLE TRANSFER WHILE AVOIDING CROSS CONTAMINATION.	A. VARIOUS MEANS OF INCREASING PO PHOTOGRAPHIC YIELD C. EXTENT TO WHICH REAL TIME PO PHOTOGRAPHIC PLANNING BY THE CREW IS EFFECTIVE.	A. VARI

SSUES COMMANDS TO: ADJUST GEOPHYSICAL INSTRUMENT SAMPLING
HEIR EXPECTED LONG DURATION VALUES; REDUCE DATA
MAINTENANCE OF DATA QUALITY; INITIATE SURFACE PROBE
OF PO PHOTOGRAPHS; PERFORM REAL TIME GEOPHYSICAL EXPERI-
OL; INITIATE PROBES - EARTH COMMUNICATION LINK ACQUISITION

MATION WITH CREW IN LOOP AT ALL TIMES

IVED FROM PROBES ONLY AS INDICATED BELOW

RRAIN PANORAMAS ~7.6 x 107 BITS
ICS INSTRUMENTS DATA ~4 x 10^6 BITS

ERRAIN PANORAMAS ~4.7 x 107 BITS
YSICS INSTRUMENTS DATA ~7 x 10^6 BITS

OGRAPHS & 2.34 x 10^8 BITS OF ORBITAL GEOPHYSICS DATA VIA BUFFERED TRANSMISSION

RELAY OF 16 PO PHOTOGRAPHS
9 BITS OF VISUAL & NON-VISUAL SURFACE DATA

GL & MSSR TRANSMISSION ~1.4 x 10^9 BITS
(MIX OF PO PHOTOGRAPHS, VISUAL & NON-VISUAL SURFACE DATA)

LIED LATER

LIED LATER

PRIATE MIX OF LAST BATCH OF FLYBY DATA (CREW IN CONSULTATION WITH EARTH IF NECESSARY)
TY LIST OF FLYBY DATA FOR TRANSMISSION TO EARTH (CREW IN CONSULTATION WITH EARTH)

NG KNOWLEDGE BASED ON ALL PREVIOUS FLYBY DATA.

OST IMPORTANT FOR EARLY MANNED LANDING MISSION

THOSE GEOPHYSICS EXPERIMENT OPTIONS WHICH MAY OCCUR

SURFACE VISUAL & NON-VISUAL DATA VIA PO FOR CERTAIN GL AND/OR MSSR COMMUNICATION SYSTEM FAILURES

S MEANS OF FURTHER MAXIMIZING SUBPHASE DATA OUTPUT

APPENDIX

This appendix identifies areas needing further study to better define operations during the encounter portion of the flyby mission. Also included is appropriate background information in support of this interim mission sequence plan. Items in both of these categories are briefly discussed below and referenced to the pertinent sections of the text.

2.0 Mission Sequence

A. A discrete number of bandwidths is prescribed because totally adaptive communications systems are considered beyond the 1975 state-of-the-art. A totally adaptive communications system automatically adjusts transmission bandwidth as a function of changing range to the receiver.

2.1.2.2.1 Pre-Separation Operations

A. The G.E. Bio-Isolator Suit System (BISS) used in conjunction with a wall pass through oven for spare parts sterilization has the capability for sterile probe repair and should be operational by 1970. However, an inflight resterilization capability may be needed as a backup in the event of a BISS or pass through oven malfunction.

B. The selection of probe repair times is somewhat arbitrary, but is intended to represent the relative complexity of the different probe types. Also, the durations chosen are considered to be long enough for reasonable voice communication with earth if probe repairs require consultation with systems experts. This area needs further inquiry to answer the basic question: how close in time prior to scheduled probe separation can a probe system anomaly be detected and successfully repaired by the crew?

C. Delayed probe injections could result from longer than anticipated probe repair times. Therefore, the influence of delayed probe injections on targeting capability within probe propulsion system constraints should be investigated.

D. In this connection, the development of a practical "range safety" procedure appears necessary.

Appendix

2.1.2.2.2 Injections

A. The final specification of injection times and the resulting launch sequence for the probes involves numerous systems and mission considerations each exerting its peculiar influence. Among the more influential of these considerations is the total velocity change required for probe injection and subsequent midcourse correction maneuvers. In this connection, it appears possible to define a probe injection time which will incur a minimum velocity change expenditure for a given early time of arrival.

For a fixed probe arrival time the injection velocity change required decreases with increasing range at probe injection. Conversely, for increasing injection range the accuracy of on-board navigation of the MM with respect to the planet decreases, thus incurring an increased total midcourse correction velocity change.* These two competing influences may result in an optimum launch time for each probe corresponding to the minimum combined injection and midcourse velocity change requirement. Such optimum launch times have not as yet been determined.

If the times of arrival of the probes were fixed, specification of optimum launch times would uniquely determine the sequence of probe injections as well as the velocity change criteria for design of the injection and midcourse propulsion systems. However, the times of arrival of the GL and MSSR probes are not fixed, but could vary from -2.5 hours to -14.5 hours, depending on the desired landing site location, which is a function of inflight probe targeting.

The indicated range in surface probe early arrival time is based on the current probe entry trajectory configuration and requirements for access to a landing site within about 180° of MM periapsis longitude, line of sight to the MM for communications, and sunlight for the performance of surface operations. The injection and midcourse propulsion systems of the surface probes must be designed for the earliest time of arrival, i.e., the maximum required velocity change.

Since the range in surface probe arrival times "brackets" the fixed PO time of arrival of -3 hours 30 minutes, the injection times of the MSSR and GL relative to that of the PO cannot be based only on velocity change considerations, thus

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*It is assumed that an on-board guidance and navigation technique is used.

generating a need for other injection sequence criteria. The tentatively adopted criterion is to inject the surface probes after the PO in order to obtain higher resolution telescope photos for targeting than could be obtained prior to PO injection. However, this criterion should not be considered unequivocal since further investigation could uncover additional criteria which may reverse the sequence.

2.1.2.2.3 Mars Approach

A. Increasingly higher resolution photos could provide the basis for a decision to change one or more probe missions. Further inquiry is needed to establish the envelopes of possible alternate missions within probe propulsion system constraints as a function of time from periapsis.

B. Assuming an on-board navigation system, the accuracy in knowledge of position and velocity of the MM (and therefore the probes) with respect to Mars should continually improve due to the steadily decreasing range, thus allowing increasingly accurate probe midcourse corrections to be performed. In this context further investigation is needed to establish the midcourse correction strategy.

C. The tradeoffs associated with transmitting tracking data to earth for computation of midcourse corrections as a backup mode and as a possible means of conserving on-board computer core storage should be investigated.

2.1.2.2.4 Mars Arrival

A. There are two potential uses of pre-arrival atmospheric information: (1) improvement of surface probe CEP's through reduction of martian atmospheric uncertainties, and (2) change in PO nominal orbital altitude based on calculated aerodynamic drag and its effect on PO lifetime. Further investigation to identify additional uses of pre-arrival atmospheric data is needed.

B. Early in the pre-programmed telescopic sequence it would not be difficult for the crew to exercise an override option in order to take advantage of "targets of opportunity". However, as periapsis is approached, the time duration for which the override option remains feasible is currently unknown due to a lack of definition of crew response time characteristics. The uncertainties in this area indicate a need for further inquiry.

2.2.1 Phase Definition

A. By manipulating the transmission equation it can be shown that the break even range is independent of the transmission system and is given by the following simple relationship:

$$R_1 = R_2 \frac{D_{R_1}}{D_{R_2}} \sqrt{\frac{T_2}{T_1}}$$

where R = range between transmitter and receiver

D_R = receiver antenna diameter

T = receiver noise temperature

subscripts

1 = transmission to MM

2 = transmission to earth

The preceding relationship is contingent on the following set of assumptions:

1. The same transmission system is used for transmission to the MM and earth.

2. Transmission to the MM and earth is at the same signal-to-noise ratio.

3. The information rate to the MM at the break even range is the same as that to earth.

2.2.2.2.1 Probe Arrivals through Checkouts

A. It is assumed that the biological condition of the PO satisfies the NASA sterilization criteria, thus allowing a low altitude orbit without endangering planetary quarantine. The 300 km circular polar orbit was chosen in order to obtain high resolution images (8 m) of the martian polar regions. It is anticipated that the PO will obtain a photographic sampling of the martian surface during this phase followed by long duration observation of seasonal surface changes using an on-board vidicon system. Seasonal observation would also include remote non-visual sensing of the atmosphere and surface while long duration tracking of the probe from earth would provide geodetic information.

PO photography over the equatorial region of the planet during the encounter portion of the mission will result in poor photographic contrast due to the orbital ground track passing approximately over the subsolar point. However, about one-eighth of a martian year later lighting conditions along the ground track will be good at all latitudes due to the inertial rotation of the terminator.

B. It is necessary to determine the means by which the PO retrograde maneuver will be performed. Since the use of an aerodynamic deboost holds the potential for a PO launch weight reduction by a factor of approximately two over that required for a purely propulsive deboost, the feasibility of an aerodynamic retrograde maneuver should be investigated.

C. Based on the trajectory currently under study, the surface probes land in the dark on a relatively undefined surface without a direct line of sight to the MM. This is a high risk situation which could result in the failure of the probe mission. Further investigation of various means of providing artificial lighting, automatic obstacle avoidance systems, or a command relay link between the crew and the descending probe is needed.

2.2.2.2.2 Pre-RV Liftoff Operations

A. The one-minute transmission time is based on the estimated minimum possible time for the facsimile camera to execute one 360° rotation. The sun elevation angle will change by approximately 1/4° during this transmission period which could cause some lack of definition of surface features in the visual data. However, this phenomenon is anticipated to exert a minor influence under the general lighting conditions prevailing during the overall one-minute transmission period.

B. The range and, therefore, time at which these experiments are to be activated as well as their required degree of automation are presently undefined.

C. With regard to optimization of surface soil sample acquisition, the advantages offered by the availability for comparison of two terrain panoramas from different landing sites under the same lighting conditions are not obvious and require further investigation.

D. The "reasonableness" of a given amount of time for terrain analysis and related decision making is currently a very subjective matter due to the absence of firm crew performance criteria and the uncertainties in the knowledge of the martian surface. For this reason the specified amount of analysis and decision making time (about 34 minutes) is primarily the result of a tentative conclusion that marginally acceptable lighting conditions prevail at a sun elevation angle of about eight degrees. For example, better lighting conditions could be obtained at the expense of analysis and decision making time by simply acquiring the MSSR facsimile panorama at a later time. In any event, the question as to what analysis and decision making the crew can execute in a given amount of time after being presented with their first view of the martian terrain requires further investigation. It is anticipated that at the very least surface obstacle avoidance could be performed.

E. Based on the 600-line Surveyor TV mode and the data rate capacity at -55 minutes (i.e., 3.1×10^7 bps), it is estimated that pictures can be transmitted at the rate of about 85 per second. This is considered to provide essentially a "real time" observation capability.

2.2.2.2.3 RV Flight

A. Due to the current coplanar RV-MM rendezvous constraint MSSR landing sites (i.e., RV launch sites) are restricted to a single continuous line on the martian surface with end points at about 37°N and 38°S latitude, separated by about 180° in longitude. This limitation, which hampers MSSR targeting flexibility, can be eliminated by providing for out-of-plane launches of the RV. Further analysis of the non-coplanar rendezvous aimed at relaxing the MSSR targeting limitation is necessary.

B. The RV profile is based on a guidance system which consists of an on-board programmed autopilot for the first two stages of powered flight. At third stage ignition the loop is closed with vehicle flight subsequently being controlled by the crew via radio command, using both optical and radar tracking information.

C. An important consideration which has previously received scant attention is the transfer of the surface samples from the RV payload to the MM in a manner such that cross-contamination is avoided. This problem requires examination in depth from both the operational and hardware points of view.

Appendix

D. Since the third stage of the RV could have martian biota on its exposed surfaces, it may be desirable to bring the entire stage on-board the MM. In this mode the third stage of the RV would serve as a backup sample.

2.2.2.2.4 Direct PO Photographic Readout

A. The subphase duration is established through the use of the transmission equation under the constraint of maintenance of the signal-to-noise ratio of photographs of Lunar Orbiter quality. The resulting relationship expressing the maximum range to the MM (R_1) as a function of the fixed data rate (B_1) for direct readout and transmission of PO photos to the MM, is:

$$R_1 = R_2 \left(\frac{D_{T_1}}{D_{T_2}}\right)\left(\frac{D_{R_1}}{D_{R_2}}\right)\sqrt{\frac{T_2 B_2}{T_1 B_1}}$$

where R = range from transmitter to receiver

D_T = transmission antenna diameter

D_R = receiver antenna diameter

T = receiver noise temperature

B = data rate

subscripts

1 = transmission from PO to MM

2 = transmission from Lunar Orbiter to earth

The information rate (B_1) is adjusted by varying the number of lines used to read out the photograph (and therefore the image resolution) as well as the linear velocity of the "flying spot" which generates the lines. To determine the fixed data rate, the 40 km x 40 km area covered by each photo is first assumed to be overlaid by 14×10^3 lines, producing 8 m resolution. The "flying spot" linear velocity is then assumed to be increased by a factor of two over that of the operational Lunar

Orbiter photo readout system. This represents the approximate upper limit of phosphor drum readout technology. The data rate so obtained is reasonably reduced by a factor of four for data compression and coding, yielding the direct readout information rate of $\sim 8.3 \times 10^5$ bps. The resulting maximum range and corresponding subphase duration are 5.54×10^5 km and 15 hours 21 minutes, respectively.

There are two schemes which appear to hold the most potential for an increase in the number of PO photos obtained during this subphase. The first is the possible development of flight weight laser photo readout systems which could greatly increase the constant readout speed for a fixed number of overlaid lines. The other is the use of a buffering or photo storage approach as a means of eliminating the direct readout data rate constraint resulting from the fixed linear velocity of the flying spot. The number of additional photos obtainable using this method must be traded against data storage volume and weight penalties as well as reliability.

B. A secondary benefit of the parallel mode of operation is that through redundancy it increases the probability of obtaining a basic minimum of 70 photographs.

C. It is anticipated that the crew would perform some degree of real time PO photographic planning. However, further investigation is needed to establish the extent to which this planning would be effective.

2.2.2.2.5 Pre-Break Even Point Operations

A. The operational configuration for this subphase is not optimized with respect to data return. For example, the system, operational, and occultation constraints determine the various discrete data rates and their corresponding time durations until signal-to-noise degradation. Where a choice exists, the rates and corresponding durations are, in general, selected on the basis of engineering judgement. Further investigation to optimize the data output for this subphase as well as the entire mission is needed.

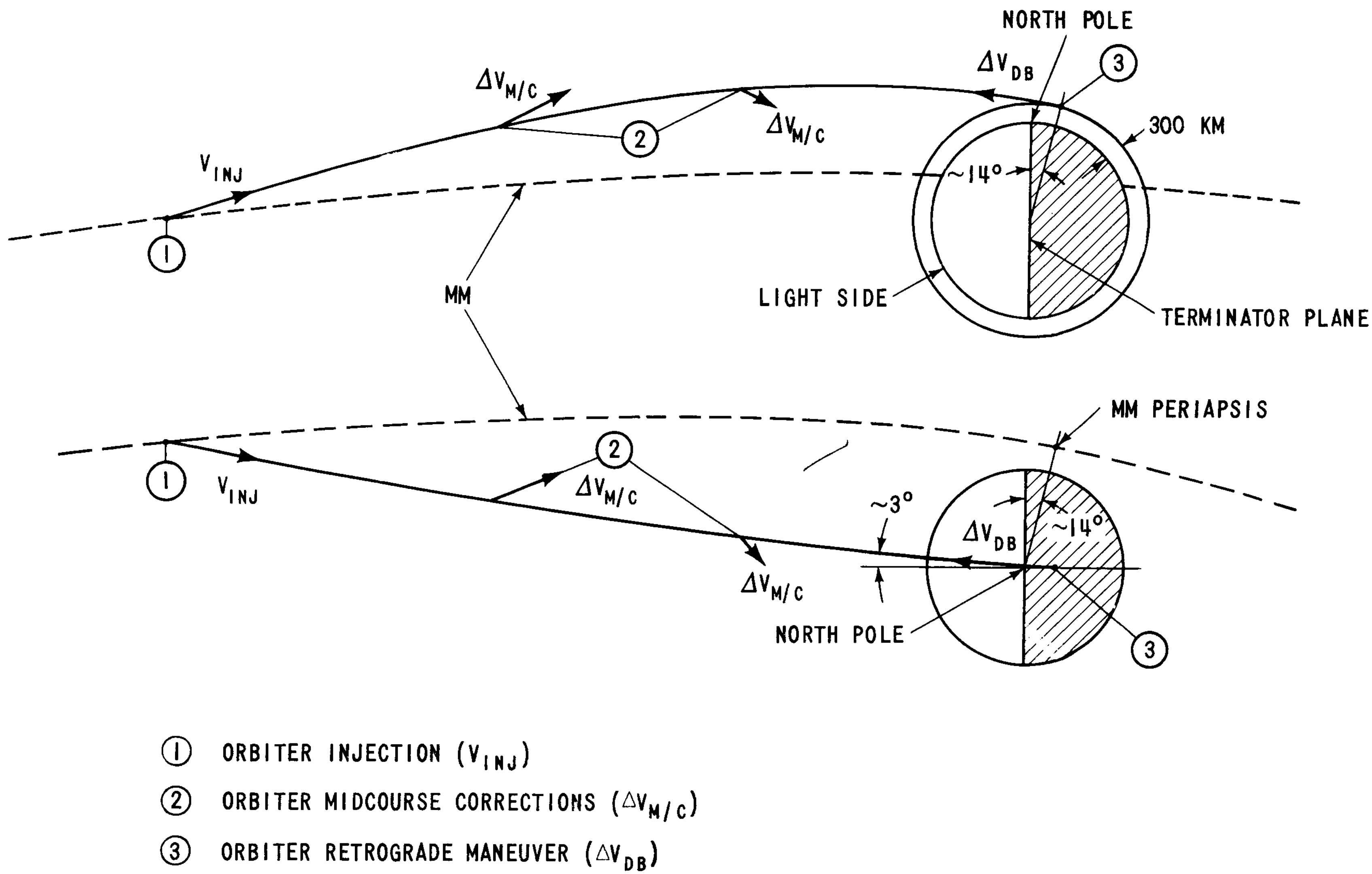
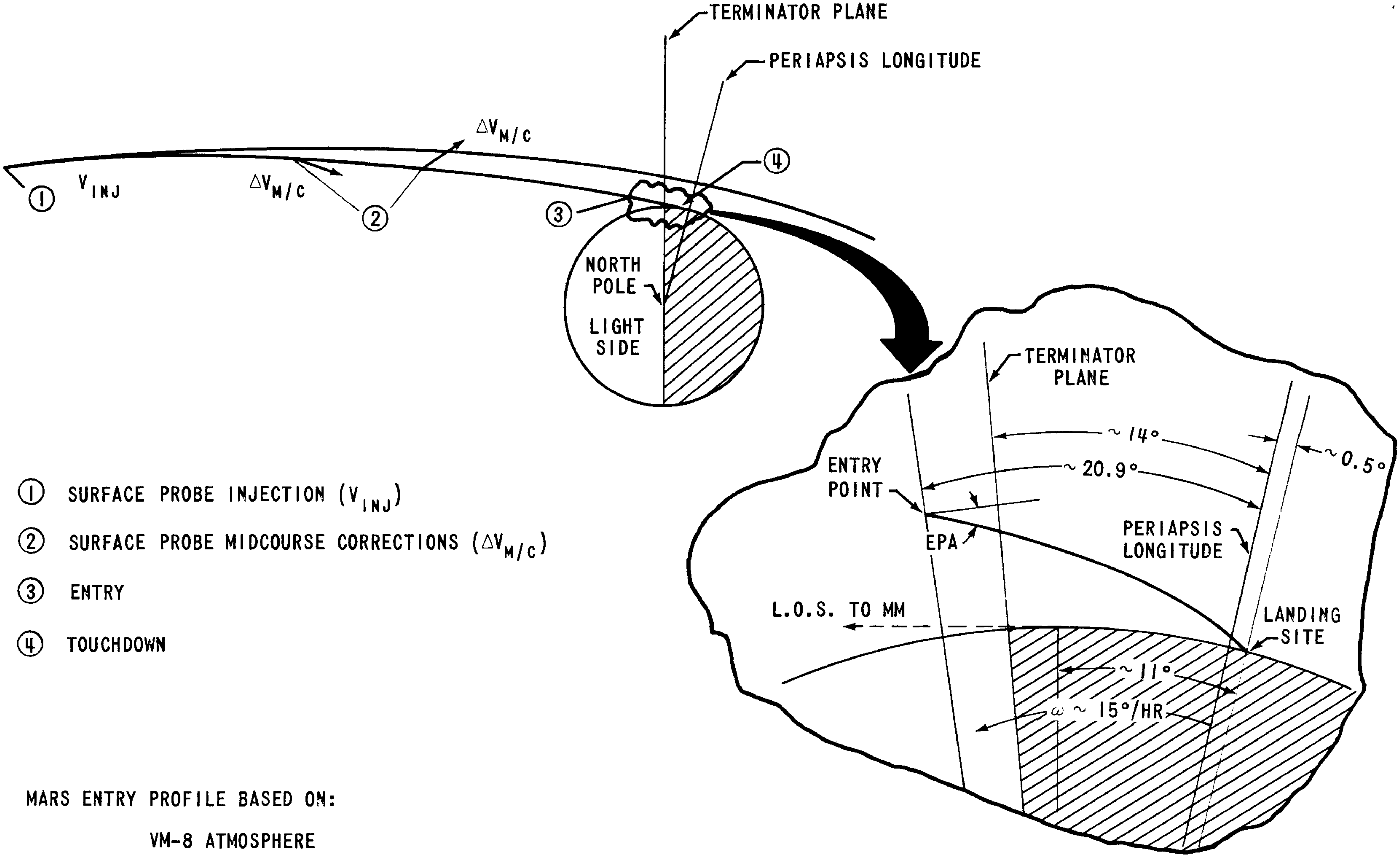


FIGURE 1 PHOTOGRAPHIC ORBITER MISSION PROFILE



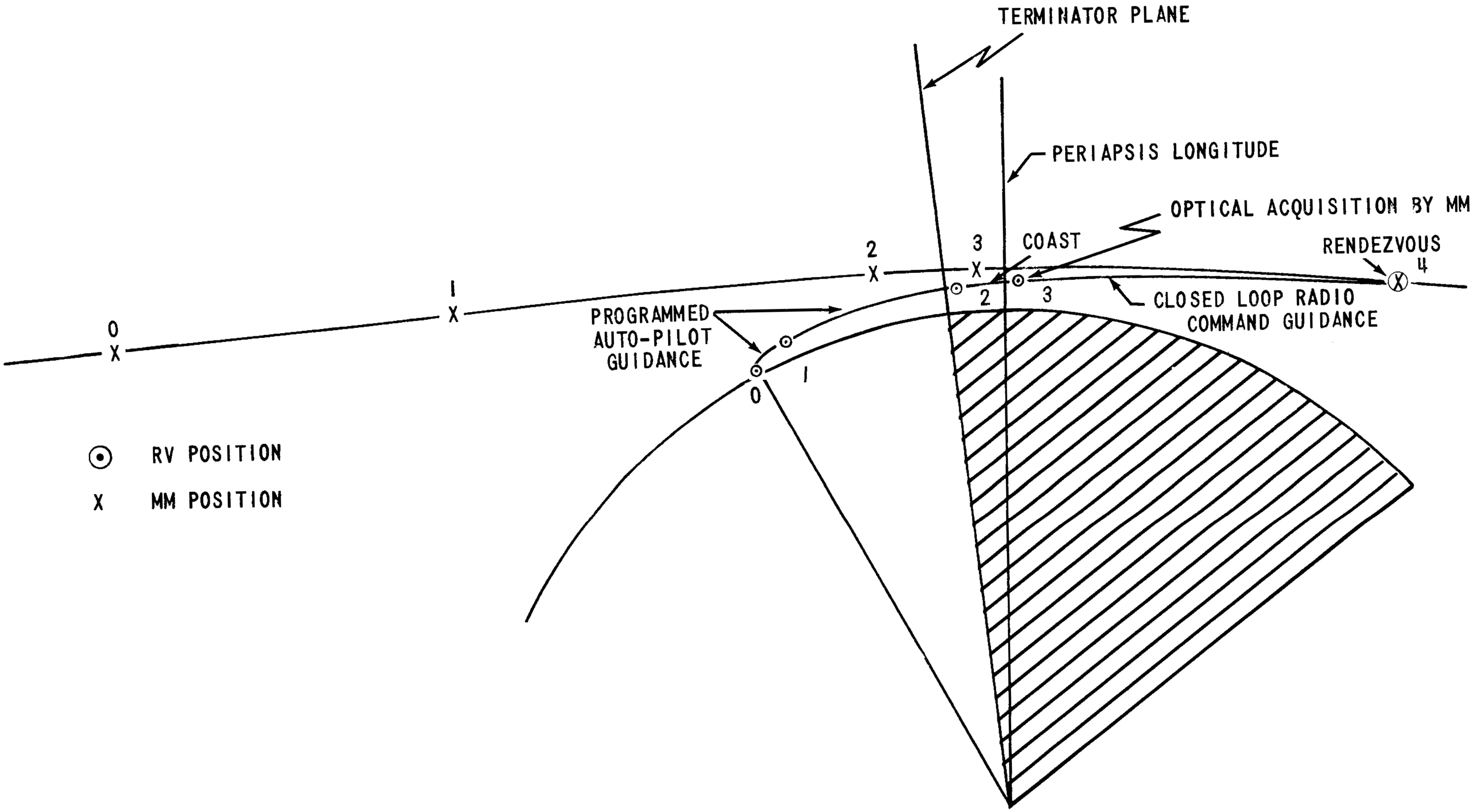
MARS ENTRY PROFILE BASED ON:

VM-8 ATMOSPHERE

PROBE $\frac{m}{C_d A}$ = .8 SLUGS/FT^2

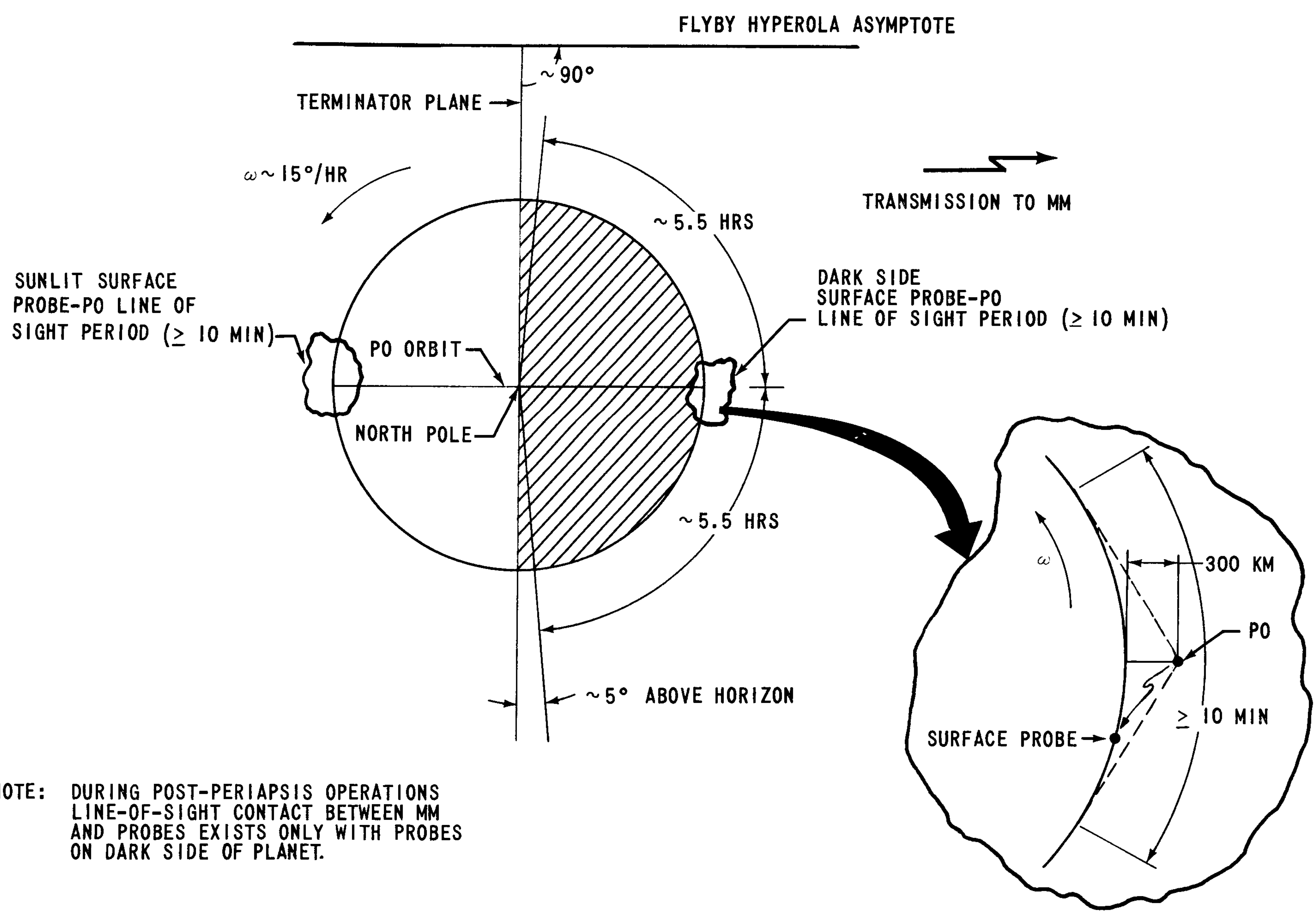
ENTRY PATH ANGLE = -18.1°; ENTRY ALTITUDE = 222KM (120NM)

FIGURE 2. SURFACE PROBE MISSION PROFILE



SYMBOL	EVENT	TIME FROM PERIAPSIS (MIN)	MM-RV RANGE (KM)
0	RV LIFT OFF	-11.5	5400
1	BURN OUT STAGE 1	-6	2470
2	BURN OUT STAGE 2	-1.5	866
3	IGNITION STAGE 3	-0.5	660
4	BURN OUT STAGE 3	+5	0

FIGURE 3. RV FLIGHT PROFILE



NOTE: DURING POST-PERIAPSIS OPERATIONS LINE-OF-SIGHT CONTACT BETWEEN MM AND PROBES EXISTS ONLY WITH PROBES ON DARK SIDE OF PLANET.

FIGURE 4 - LINE OF SIGHT CONSIDERATIONS FOR POST-PERIAPSIS OPERATIONS

BELLCOMM, INC.

Subject: Interim Mission Sequence Plan for the Encounter Portion of the 1975 Manned Mars Flyby Mission - Case 233

Date: June 15, 1967

From: E. M. Grenning

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